Margaret Houghton

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MODERN GEOGRAPHY

FOR HIGH SCHOOLS

BY

ROLLIN D. SALISBURY

HARLAN H. BARROWS

AND

WALTER S. TOWER

Of the Department of Geography, the University of Chicago

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PREFACE

For several years there has been a widespread demand for a course in general geography in high schools. This book is designed to serve as the basis for such a course. All rational work in general geography must be founded on physiography, and this fact has determined the organization of the material of this book. Physiographic processes and features are treated briefly, however, while their relations to life, and especially to human affairs, are developed at greater length. The book has been prepared with the conviction that the chief object in geography teaching should be preparation for everyday life, for citizenship in the widest sense. Hence the authors constantly have sought (1) to make the text explanatory rather than merely descriptive, so that it may afford training in clear thinking; and (2) to emphasize the relations of earth, air, and water to man's activities and interests, so that the knowledge gained may be directly useful.

The principles developed have been applied at greatest length to the United States, because this country is of most interest and importance to American students. Furthermore, space forbade the application of these principles in detail to other countries.

The larger aspects of economic and commercial geography are covered in connection with such topics as soils, minerals, waterways, water power, harbors, and the distribution and development of industries and cities. It is hoped, therefore, that the book may be found useful by teachers of commercial geography, as well as by those who have sought to "humanize" high school physiography.

The illustrations are intended to serve as the basis for classroom discussions and quizzes, and should be studied and interpreted as carefully as the text itself. The questions may be used for written work or for classroom discussion. The answers to most of them are not to be found in the text, but can be reasoned out by students who have followed the text with understanding. The physical maps at the end of the book afford the means of locating most of the places and features mentioned in the text.

Teachers using this book will find it helpful to have the authors' Elements of Geography. The larger volume discusses in greater detail many of the topics of this one, and gives numerous references to supplementary material. A list of books on geography and related subjects which might well be in a high school library is given at the end of this book.

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AT END OF VOLUME

MODERN GEOGRAPHY

CHAPTER I

THE NATURE OF GEOGRAPHY

Ancient and modern geography. Geography has been studied since ancient times, for people always have wanted to know about the earth on which they lived; but the conception of geography has changed greatly as years have gone by. In olden times it was regarded as a description of the earth. It included an account of the countries into which the earth is divided, their physical features, such as rivers, mountains, and plains, and their inhabitants and products. Modern geography is concerned especially with the effects of physical features, such as land forms, water, and climate, on living things.

Divisions of geography. It is clear that there are two main parts to the study of geography: (1) The physical features of the earth (land, water, air) which affect life; and (2) the ways in which different forms of life respond to their physical surroundings.

Various groups of *physical phenomena* may be the subjects of special study. Thus the phenomena of the atmosphere are considered in *meteorology* and *climatology;* those of the waters in *oceanography* and *hydrography;* and those of the lands in *physiography*, as some would define that term. Similarly, *earth relations to life* may be studied with special reference to plants (*plant geography*), to animals (*animal geography*), or to man (*human geography*).

Relations to other subjects. The study of these different phases of geography brings it into contact with many other sciences. The form, size, and motions of the earth are matters of *astronomy* as well as geography; the origin and characteristics of land forms and the distribution of useful minerals are matters of *geology* as well as geography; the effects of physical conditions on plant and animal

life are phases of *botany* and *zoology* as well as geography; the distribution of mankind, man's subdivision of the earth into political units, and many other matters, relate geography closely to *history;* and man's present activities, influenced by geographic conditions, are factors of *political economy*.

Importance of human geography. Most interest attaches to the study of the earth in its relations to man. Human activities are so many and varied, and are influenced in so many ways by physical conditions, that special study often is made of related effects. Thus *economic geography* traces the influence of natural factors in the production of things useful to man. The relations of land forms, soil, and climate to the raising of crops is an example. *Commercial geography* considers the influence of natural factors in the transportation and exchange of various commodities, as the trade in tropical fruits between warm regions and those too cold to raise them. *Historical geography* is concerned with the influence of physical conditions on past events. *Political geography* traces the influences of location, topography, climate, and natural resources on the development of countries.

The basis of other studies. Since geography shows the many ways in which the earth is related to the life of man, it is important as the basis of many other studies. It is especially important in connection with the study of *history*, for in all ages the conditions under which people lived have influenced their occupations, their stage of development, and their relations to the rest of the world. The better geography is understood, therefore, the easier it is to understand the meaning of historical events. The Jews in Palestine never became seamen because the nearest coast had no good harbors, while their neighbors, the Phœnicians, on a more favorable coast, were the first good sailors, and for many years were influential in Mediterranean districts outside their own country. Russia has striven for more than two centuries to secure satisfactory seacoasts, and as a result has been led into several wars with her neighbors. Great Britain, difficult to invade because an island, was able at an early date to use her natural resources to great advantage, and became the leading nation of the world in manufacturing and commerce. In our country, slavery developed chiefly in the South, mainly because the conditions of field labor there favored it more than in the North. These examples suggest the close connection between geography and some important facts and phases of history.

Geography is related no less intimately to *present events*. The distribution of people over the face of the earth, the manner in which they live, and their grouping in countries and cities always bear some relation to earth conditions. Many old cities, like Venice, were located where defense against invasion was easy. Most new cities were located with respect to natural advantages for manufacturing or commerce. Food, dress, shelter, occupations, industries, products, trade, and many other facts and conditions of life are influenced by physical surroundings. Deserts have little vegetation and few animals, for water is scarce. Since man depends on plants and animals for food and clothing, and largely also for shelter, desert populations are small.

Tropical natives wear little clothing and eat little meat, largely because bodily temperatures are maintained easily without either. They have little commerce, because their wants are few. The people of middle latitudes, on the other hand, must adapt themselves, in the matter of food, clothing, and shelter, to extremes of heat and cold. Their wants are therefore many and varied. Complex industries and world commerce are needed to satisfy them. The United States is the greatest producer of foodstuffs, because of the great extent of favorable surface, soil, and climate — resources which a progressive people have used to advantage. Several countries of western Europe have advantages for extensive manufacturing, such as supplies of coal near good seaports; but they cannot produce all the raw materials needed for their factories, nor all the food for their factory workers. Hence large quantities of raw materials and food, like cotton and copper, flour and meat, are exported yearly from the United States to these European countries.

An understanding of the larger relations between physical conditions and life in general is necessary for an understanding of the effects of the physical surroundings of man on his interests and activities. This in turn helps one to understand the affairs of the world, and therefore is important to good citizenship.

CHAPTER II

EARTH RELATIONS

The Solar System

Members of solar system. The solar system includes the sun and all the bodies which revolve about it (Fig. 1). There are eight *planets*, of which the earth is one. To us, all the planets except our own appear as stars, but in their motions they differ from other stars. Commencing with the nearest to the sun, the planets are,

Fig. 1. Diagram of the principal members of the solar system. The size of the bodies is exaggerated greatly as compared with that of the sun and the orbits. The central body is the sun; the others are the planets.

in order: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. All but Mercury and Venus have *satellites* corresponding to our moon. Saturn has nine of them.

Besides the planets and their satellites, the solar system includes numerous other bodies (mostly *asteroids*) which have little influence on the earth.

The sun is more than 1,000,000 times as large as the earth, and very hot. From it the earth receives nearly all its heat and light. The other planets shine only by reflected sunlight.

Beyond the great system to which the earth belongs there are many thousands of stars, each of which may be compared to our sun, though many of them are vastly larger.

The planets. The planets are all of similar form, all rotate on axes, and move in nearly circular paths about the sun in the same direction, but they are strikingly unlike in some respects. Jupiter,

the largest, has a diameter more than ten times that of the earth, while the diameter of Mercury, the smallest planet, is only about one-third that of the earth. The innermost planet revolves about the sun in 88 days, the outermost in 165 years. The shortest rotation period of a planet is less than 10 hours, while that of Venus is nearly 225 days. From the standpoint of life, the earth is the most favored of the planets. Indeed, the conditions of heat and light would prevent the existence of such life as we know on most of the other planets.

The Earth as a Planet

Form. The form of the earth is very much like that of a sphere, but since it is not exactly a sphere, it is called a *spheroid*. The form has been determined in various ways: (1) Ships have sailed around it. This proves that it is everywhere bounded by curved surfaces, but it does not prove that it is a sphere or even a spheroid, for it would be possible to sail around it if it had the shape of an egg. (2) When a vessel goes to sea, its lower part disappears first, and when a vessel approaches land, its highest part is seen first from the land. By people on the vessel, the highest lands are seen first, and the low ones later; the spires and chimneys of buildings appear before the roofs, and the roofs before the lower parts. Like (1) above, these facts show only that the earth has a curved surface. But from whatever port vessels start, and in whatever direction they sail, objects on land disappear at about the same rate. This means that *the curvature of the surface is nearly the same in all directions.* A body whose curvature is the same in all directions is a sphere, and a body whose curvature is nearly the same in all directions is nearly a sphere. (3) Again, the earth is sometimes between the sun and the moon. It then casts a shadow on the moon (making an eclipse), and this shadow always appears to be circular. In these and other ways it is known that the form of the earth does not depart greatly from that of a sphere. (4) That the earth is *not exactly round*, however, is shown in various ways. For example, a body weighs slightly more in high latitudes than in low latitudes. This means that it is nearer the center of the earth in the high latitudes than in the low; or, in other words, that the earth is not a true sphere. (5) Certain mathematical calculations not given here (for one of them, see p. 11) prove that the curvature of the earth's surface is less in high latitudes than nearer the equator.

Consequences of the earth's form. The spheroidal form of the earth facilitates travel and transportation. It aids commerce in another important way. The attraction of the earth causes bodies to have weight. Because the earth is nearly round, gravity is nearly equal everywhere upon its surface, and, as we have already seen, the weight of a given object is therefore nearly constant. If the weight of things varied greatly from place to place, this variation would interfere seriously with trade between different parts of the world.

Size. The circumference of the earth is nearly 25,000 miles, and its diameter nearly 8,000 miles. Since the earth is not a perfect sphere, its various diameters and circumferences are not exactly equal. Its longest diameter is 7,926.5 miles and its shortest nearly 27 miles less (7,899.7 miles). The area of the earth's surface is nearly 197,000,000 square miles.

Motions

The earth has two principal motions: (1) It rotates on its shortest diameter, called its *axis*, and (2) it revolves around the sun. The axis is an imaginary line, and its ends are the *poles*. The circumference midway between the poles is the *equator*.

Rotation. The rotation of the earth from west to east gives us day and night, for one side of the earth and then the other is turned toward the sun during each rotation. The time of rotation, about 24 hours, determines the length of a day (day and night).

Human activities are in general adjusted to the turning of the earth, the succession of daylight and darkness affording convenient intervals for work and rest. In those parts of the earth where the intervals of light and of darkness are many days (instead of hours), this habit of regularity of work and rest is less general. During the long period of light, the hunting people of Greenland, for example, cease their work or seek rest only when fatigue overtakes them. During the long period of darkness they have no regular work or exercise, and are much less vigorous than in the period of light. The long "night" of polar regions is very trying to the health and strength of people accustomed to a period of light each day.

The period of rotation furnishes also a natural unit for measuring time. Again, the rising and setting of the sun, due to the earth's rotation, give us a simple system of directions.

Revolution. The earth revolves about the sun in a little more than 365 days, and the period of revolution fixes the length of the year.

The path of the earth around the sun is its *orbit.* The orbit of the earth is not a circle, but a curve called an *ellipse* (Fig. 2), and the distance of the earth from the sun varies from time to time. When

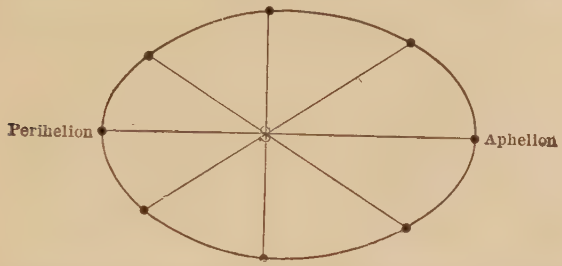


Fig. 2. The orbit of the earth is an ellipse, with the sun in one of the foci.

the earth is nearest the sun (*perihelion*), the distance between them is about 3,000,000 miles less than when they are farthest apart

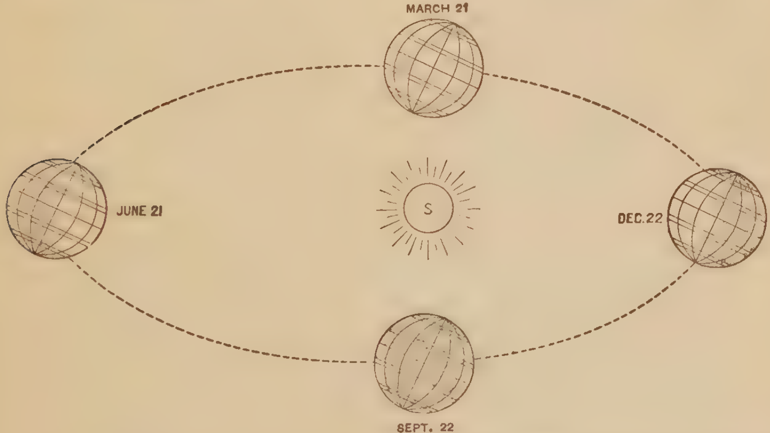


Fig. 3. Diagram showing the position of the earth with reference to the sun at the solstices and equinoxes, and the inclination of its axis.

(*aphelion*). The earth is nearest the sun (about 91,500,000 miles) in the early part of the winter of the northern hemisphere (about January 1st), and farthest from it (about 94,500,000 miles) early in the summer. The motion of the earth through space during its

revolution about the sun is at the rate of about 600,000,000 miles a year, or more than 1,100 miles each minute.

The earth's axis is inclined toward the plane of its orbit about 23½ degrees (Fig. 3). This position of the axis, together with the motions of the earth, has much to do with the distribution of the heat and light received from the sun, with the changes in the length of day (daylight) and night, and with the seasons.

Latitude, Longitude, and Time

Latitude. The *equator* has been defined as the circle about the earth midway between the poles. Circles parallel to the equator are *parallels*. The number of parallels which might be drawn is very large, though only a few are represented on maps. The length of parallels varies greatly, those near the equator being longer,

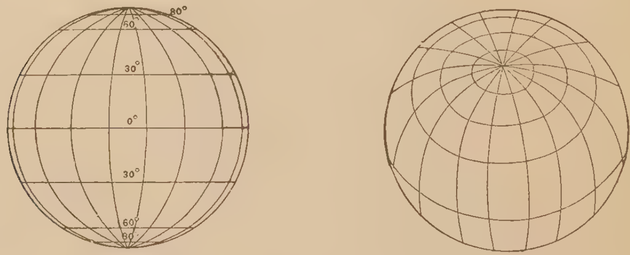


Fig. 4. Parallels and meridians.

and those near the poles shorter. The north and south lines that pass from pole to pole on the earth's surface are *meridians*. All meridians come together at each pole.

A few meridians and parallels appear in Fig. 4, which shows the earth in two positions. The left-hand part of the figure shows the half of each parallel represented and the whole of each meridian. The right-hand part shows the relation of parallels to the North Pole. The distance between the equator and either pole is divided into 90 parts, called *degrees* (written 90°). Each degree is divided into 60 parts, called *minutes* (60′). Each minute is divided into 60 parts, called *seconds* (60″). Distance north or south of the equator may therefore be determined from a globe or map by means of parallels. The system of parallels and meridians is made possible by the form of the earth and its rotation on its axis.

Distance north or south of the equator is called *latitude*. *North latitude* is north of the equator, and *south latitude* is south of it. The degrees, minutes, and seconds are numbered from the equator toward the poles. The latitude of the equator is 0°. Latitude 1° N. is one degree north of the equator, and latitude 90° N. is at the North Pole. Latitude 1° S. is one degree south of the equator, and latitude 90° S. is at the South Pole.

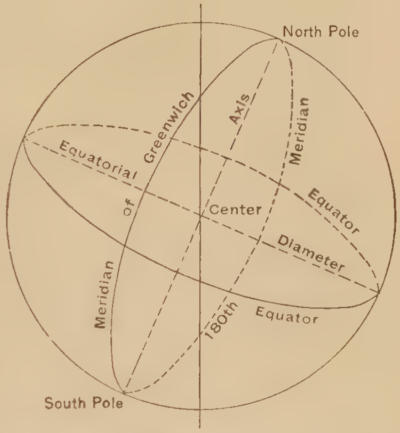


Fig. 5. Diagram showing the position of the axis of the earth, the poles, the equator, the meridian of Greenwich, and the meridian of 180°.

Longitude. Position on a parallel is indicated by means of the meridians which cross it. The number of possible meridians is very great, but, as in the case of parallels, only a few are commonly shown on maps. One meridian, that passing through Greenwich, England, where the British Royal Observatory was established in 1675, is usually chosen as the meridian from which distances east and west are reckoned (Fig. 5). This meridian is the meridian of 0°, and is sometimes called the *prime meridian*. Distance east or west of this meridian is known as *longitude*. Places east of longitude 0° are in *east longitude*, and those west of it are in *west longitude*. East and west longitude respectively are regarded as extending 180° from the meridian of 0°; that is, half-way around the earth.

The position of a place on the earth's surface may be fixed exactly by means of meridians and parallels. If a place is in longitude 30° E., its distance east of the meridian 0° is known. If at the same time it is in latitude 30° N., it must be on the parallel of 30° N. where it is crossed by the meridian of 30° E. So convenient and accurate is this method of locating places and reckoning distance, that parallels and meridians are used in many places as boundaries between states, counties, and townships.

The poles are the only places which have latitude but no longitude. Since all meridians come together at the poles, the poles cannot be said to lie either east or west of the meridian of Greenwich. At the

North Pole the only direction is south, and at the South Pole the only direction is north.

Longitude and time. There is a definite relation between longitude and time. Since the earth turns through 360° in 24 hours, it turns 15° in one hour, and 15′ of longitude in one minute of time. The sun therefore rises one hour earlier at a place in longitude 0° than at a place in the same latitude in longitude 15° W., and one

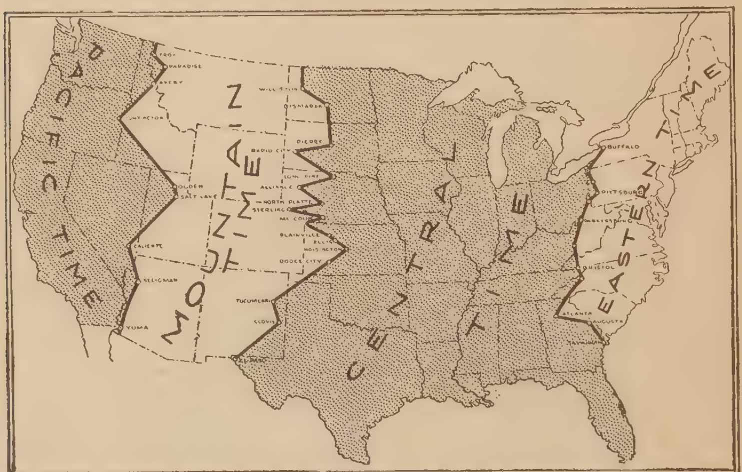


Fig. 6. Map showing standard time belts of the United States in Dec., 1912.

hour later than at a place in the same latitude in longitude 15° E. Similarly, noon comes an hour earlier in longitude 0° than in longitude 15° W., and an hour later than in longitude 15° E. All places on a given meridian have noon at the same time and midnight at the same time, and such places are said to have *the same time;* but places on different meridians have different times. St. Louis is about 15° farther west than Philadelphia, and Denver is about 15° west of St. Louis. When it is noon at Philadelphia it is about eleven o'clock at St. Louis and ten at Denver. When it is one o'clock at Philadelphia it is noon at St. Louis and eleven o'clock at Denver, and when it is noon at Denver it is one o'clock at St. Louis and two at Philadelphia.

The variations of time with changes of longitude become apparent when long journeys are made either east or west. Thus a watch which

has the correct time in New York has not the correct time when it is carried to Chicago. To avoid the difficulties of time-keeping growing out of travel, the railroads of the United States have adopted a system of *standard time.* Under this system the country is divided into north-south belts of convenient width (Fig. 6), and in each belt all railways use the same time. The railway time in adjacent belts differs by one hour. By this system, clocks and watches do not show correct *local* time except on one meridian of each belt. The irregular boundaries of the belts are due to the adoption of the nearest important railway points as the places for changing time on east and west journeys.

Lengths of degrees. The length of a degree of longitude, as measured on the surface of the earth, is the $^1/_{360}$ part of a parallel. Since the parallels are very much shorter near the poles than near the equator, the length of a degree of longitude is less in high than in low latitudes. At the poles, where the length of the parallel becomes zero, the length of a degree of longitude also becomes zero. At the equator, a degree of longitude is a little more than 69 (69.16) miles.

Degrees of latitude are measured on meridians. They also vary in length. The length of a degree of latitude is about 68¾ miles in India, while in Sweden, the most northerly place where a degree has been measured, it is 69¼ miles. All measurements which have been made show that the length of a degree of latitude, measured on the earth's surface, increases as the poles are approached. At the poles it is calculated that it must be about 69⅜ miles. In the United States, the average length is about 69 miles. The increase of length of the degree toward the poles means that the earth is flattened there. This means that the earth is a *spheroid.*

Inclination of Axis and its Effects

The sun's rays illuminate one-half of the earth all the time. The border of the illuminated half is called the *circle of illumination* (Fig. 7). All places on one side of the circle of illumination have day, while all places on the other side have night. If the axis about which the earth rotates were perpendicular to the plane in which the earth revolves about the sun, the circle of illumination would always pass through the poles. Under these conditions, half of the equator and half of every parallel of latitude would be illuminated all the time, as in Fig. 7. If the half of each parallel were always illuminated, the days and nights would be equal everywhere, for it

takes just as long for a place at A (Fig. 7) to move to B (six hours, half of a twelve-hour day) as for it to move from B to A' (half of a twelve-hour night). Since days and nights are not equal at all seasons in most parts of the earth, it proves that the axis on which the earth rotates is not perpendicular to the plane of its orbit.

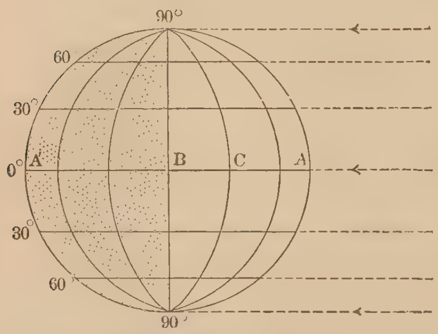


Fig. 7. Diagram to illustrate the fact that half of the earth is lighted by the sun at any one time. The parallel lines at the right show the direction of the sun's rays. The part of the earth not shaded is lighted by the sun; the other half is in darkness. The line between the illuminated half and the half which is not illuminated is the *circle of illumination*. This diagram represents conditions at the time of an equinox.

Again, if the earth rotated on an axis perpendicular to the plane of its orbit, the sun always would be equally high at any given place at the same hour of the day. But this is not the case. In the United States, for example, the sun is much higher above the horizon at noon in summer than in winter. The same is true in all latitudes similar to those of the United States.

This variation of the angle at which the sun's rays strike the same place at different times, as well as the unequal lengths of days and nights in most places, is the result of the inclination of the axis on which the earth rotates as it revolves around the sun (Fig. 3). The position of the axis is constant throughout the year. The effect of the inclination of the axis is illustrated by Fig. 3, which represents the earth in four positions in its orbit. On March 21st, the half of each parallel (the half toward the reader) is illuminated. At this time, therefore, days and nights are equal everywhere. On June 21st, more than half (the part not shaded) of every parallel of the northern hemisphere is illuminated, and there the days are more than 12 hours long and the nights correspondingly less. In the southern hemisphere the nights are longer than the days. On September 22d, the days and nights are again equal everywhere, for the circle of illumination divides every parallel into two equal parts. In the figure, the lighted part is away from the reader. On December 22d, more than half of each parallel in the southern hemisphere is in the light, and there the

days are longer than the nights, while in the northern hemisphere the nights are longer than the days. Twice during the year, therefore, on March 21st and September 22d, the days and nights are equal everywhere. These times are known as the *equinoxes*. The equinox in March is the *vernal equinox;* that in September is the *autumnal equinox*.

When the earth is in the relation to the sun shown in the position marked June 21st, Fig. 3, the days are longest in the northern hemisphere, the sun is highest in the heavens at noon, and its rays fall perpendicularly on the surface of the earth farther north (23° 27′+) than at any other time. This is the *summer solstice* (Fig. 8). The *winter solstice* occurs six months later, when the sun's rays strike the earth vertically 23½° (nearly) south of the equator (Fig. 9), and when the days of the southern hemisphere are longest and those of the northern shortest. Figs. 7, 8, and 9 also show that the *days and nights are always equal at the equator*, since the equator is always bisected by the circle of illumination. Days and nights are not always equal in any other

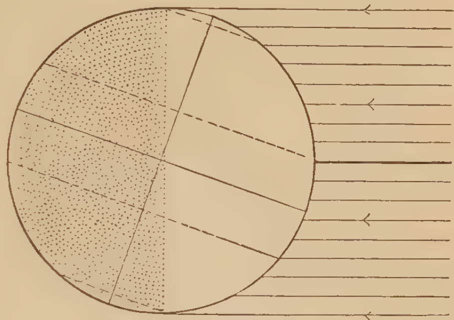


Fig. 8.

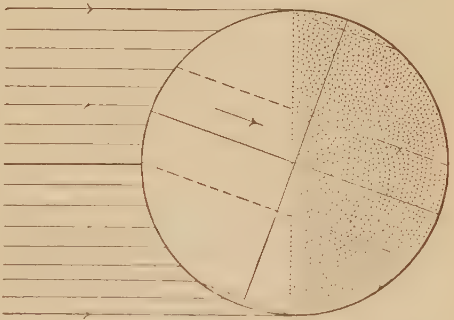


Fig. 9.

Fig. 8. Diagram illustrating the effect of inclination of the earth's axis on the length of day and night. In the figure, more than half of every parallel of the northern hemisphere is illuminated. The days in the northern hemisphere are therefore more than twelve hours long, since the half of each parallel is the measure of 180° of longitude, and 180° of longitude corresponds to twelve hours of time. Similarly less than half of every parallel of the southern hemisphere is illuminated, and the days are therefore less than twelve hours long.

Fig. 9. The relation of the earth to the sun's rays at a time six months later than that represented in Fig. 8. The conditions of day and night in the hemispheres are reversed.

latitude, unless at the poles, where there is one day (or period) of six months of light, and one night (or period) of six months of darkness.

The relative duration of daylight and darkness, and the angle at which the sun's rays strike the earth, are the chief causes of changes of seasons. Thus at the equator, where the hours of day and night are always equal, and the sun's rays nearly vertical at all times of the year, seasons differ but little, while toward the poles, say in Lat. 60°, where days and nights are very unequal most of the time, seasons differ greatly.

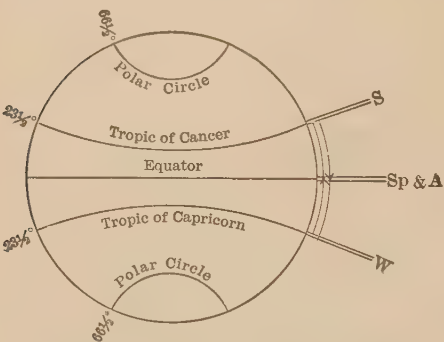


Fig. 10. Diagram illustrating the apparent motion of the sun.

It will be seen, therefore, that most of our methods of reckoning years, seasons, days, distances and positions, weights, and directions depend on the various earth relations.

Apparent motion of the sun. The effect of the inclination of the axis of the earth is *to make the sun appear to move north and south* once during each revolution of the earth about the sun. That is, the revolution of the earth about the sun, while it rotates on an inclined axis, makes the sun appear to move from a place where its rays are vertical 23½° (nearly) north of the equator (direction *S*, Fig. 10), to a place where they are vertical 23½° (nearly) south of the equator (direction *W*), and back again, in one year. The result, so far as the earth is concerned, is as if the sun moved from *S*, which corresponds to the time of the summer solstice, to *Sp & A*, which corresponds to the time of the autumn equinox, then to *W*, which corresponds to the time of the winter solstice, then back again to *Sp & A*, which corresponds to the spring equinox, and finally to *S*, while the earth is making one circuit about the sun.

When the sun is vertical at points north of the equator, the days are longer than the nights in the northern hemisphere, and the sun's rays strike the surface in the northern hemisphere more nearly vertically than they do in the southern hemisphere. The greater number of hours of sunshine and the more nearly vertical rays explain the

warmth of our summer, even though the earth is then farthest from the sun. In high latitudes, as in western Canada, the long period of sunlight (16 to 18 hours) is an important factor in the successful cultivation of crops, in spite of the short summer. When the sun is vertical at the equator, days and nights are equal everywhere, and when the sun is vertical south of the equator, days are longer than nights in the southern hemisphere, and the sun's rays are more nearly vertical there than in the northern hemisphere.

The northernmost parallel where the sun's rays are ever vertical is called the *tropic of Cancer.* The corresponding southernmost parallel is the *tropic of Capricorn.* The tropics are nearly 23½° (23° 27′+) from the equator, because the axis of the earth is inclined by that amount toward the plane of its orbit. The sun is vertical at the tropic of Cancer at the time of the summer solstice, and at the tropic of Capricorn at the time of the winter solstice. The parallels just touched by the circle of illumination at the time of the solstices are the *polar circles.* They are as far from the poles as the tropics are from the equator. They are therefore in latitude about 66½°. The one in north latitude is the *Arctic circle*, and the one in south latitude is the *Antarctic circle.*

Within the polar circles the differences of the seasons are chiefly a matter of daylight and darkness. Between the tropics there are no changes of seasons like those of the United States. Hence it is only between the polar circles and the tropics that there are four seasons of the year, to be called truly spring, summer, autumn, and winter.

Maps and Map Reading

What is known of the earth's surface may be represented in various ways — by globes, models, and maps. Globes have the great advantage of showing without distortion the distribution of land and sea, and other large surface features. It is not practicable, however, to make them large enough to show minor features, and, even apart from this, they are not suited to all purposes. Models, or relief maps, reproduce on a small scale the unevenness of the earth's surface. In order that the elevations may stand out clearly, their height is exaggerated greatly on most models, which are likely, therefore, to give false impressions.

Map projections. The necessity of representing part or all of the earth on a flat surface led very early to the making of crude maps.

It is, of course, impossible to show the rounded surface of the earth on a flat surface without exaggerating or reducing certain parts, so that each of the many methods (*projections*) devised from time to time for representing the meridians and parallels of a globe on a plane surface, involves more or less distortion.

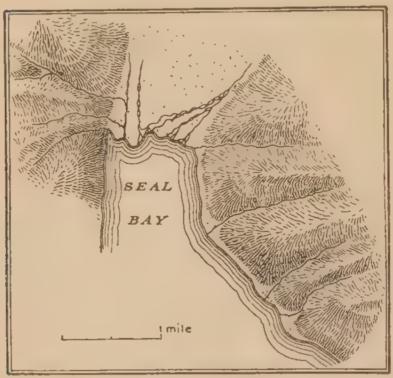


Fig. 11. Map representing relief by hachures. (U. S. Geol. Surv.)

Almost all sailing charts and many maps of the entire world are made on *Mercator's projection* (Fig. 39), named for the inventor. A map on Mercator's projection is accurate at the equator, but exaggerates areas more and more as the poles are approached. Thus Greenland (Fig. 39) appears to be about half as large as North America on a Mercator's map, while in reality it is less than one-fifteenth as large.

Representation of relief on maps. The surface of the land is uneven, and it is a matter of importance, in many cases, to show the unevennesses (*relief*) on maps. This is done in various ways. One method is by shading — different colors or shades representing different elevations (see maps at end of book). Another method is by *hachures* (Fig. 11) — lines drawn in the direction in which the land slopes. Where slopes are steep, the lines are made short and heavy; where gentle, longer and lighter. Such maps give only a general idea of the form of the land.

Much more exact information may be had from *contour-line* maps. In order to read contour-line maps, it is necessary to know that *contours* are lines drawn on maps to express relief, and that any given line runs through points of the same elevation above sea-level. This will be understood readily by reference to Figs. 12 and 13. Fig. 12 shows a model of an ideal landscape viewed from above, on which lines have been drawn connecting places of equal elevation. In Fig. 13 the above lines are shown alone; this is a contour map of the region represented by the model. By comparison of the model and map it will be seen that where the slopes of the former are steep

the lines of the latter are close together, and *vice versa*. The vertical distance between two adjacent contour lines is the *contour interval.* The contour interval varies on different maps. In regions of low

Fig. 12. Model of ideal landscape. (Keeler.)

Fig. 13. Contour map of the area shown in Fig. 12. (U. S. Geol. Surv.)

relief an interval of 10 or 20 feet generally is used; in mountainous areas an interval of 500 or more feet has to be used in some cases in order to avoid having the lines too close together to be read. In the map of Fig. 13, the interval is 20 feet, the exact value of the 100

and 200 foot lines being indicated. By counting the lines it will be seen that the top of the hill to the left of the river is more than 260 feet above the level of the ocean in the foreground. It cannot be 280 feet high, however, for no 280 foot line is drawn. A comparison of the model and map will show also how valley depressions are represented by contours.

Terrestrial Magnetism

The earth is a great magnet, and, like the small magnets with which we are familiar, has two poles. One of these poles is called the *North Magnetic Pole* and the other the *South Magnetic Pole*. One end of the compass needle points toward one of these poles, and the other toward the other. If we were to follow the directions pointed by the compass needle, we would be led to the North Magnetic Pole in the one case, and to the South Magnetic Pole in the other.

The magnetic poles are far from the geographic poles, the true north and south points, and they are not exactly opposite each other. Their positions appear to shift a little from year to year, but the change is not known to be great. The North Magnetic Pole is in latitude about 70° N., and in longitude 97° or 98° W., while the South Magnetic Pole is in latitude 72° 25′ S., and longitude 155° 16′ E.

Questions

1. The horizon of a given observer increases as he rises. What does this prove concerning the shape of the earth's surface at that place? What further inference could be made from the fact that as he ascends his horizon remains circular?

2. At places east of a given point the sun rises and sets before it does at that point. At places toward the west it rises and sets after it does at the station in question. What does this indicate as to the surface of the earth?

3. Why do the sun's rays never fall vertically in latitudes higher than 23½°?

4. Certain crops are said to mature faster in western Canada than farther south in the United States. Suggest a logical reason for this.

5. How would the seasons at Chicago (42° N.) be changed if the axis of the earth were inclined 45°, rotation remaining as now?

6. Two cities about 690 miles apart, on the same meridian, are located in latitude 42° N. and 32° N., respectively. From these facts determine approximately the circumference of the earth.

7. What is the difference in longitude of two places having a difference in time of six and one-half hours?

8. What is the difference in local time between New York City (74° W.) and Chicago (87° 36′ W.)?

9. The altitude of the sun at a given place at noon at the time of equinox is 50°. What is the latitude of the place?

10. In what latitudes is the altitude of the sun 20° at noon at the time of equinox?

11. In what latitudes has the sun a noon altitude of 30° at the time of the summer solstice?

12. What is the altitude of the sun at the equator at noon at the time of the summer solstice?

CHAPTER III

RELIEF FEATURES OF THE EARTH

The surface of the land is uneven. The lowest lands are below sea-level, and the highest point (Mt. Everest, in the Himalaya Mountains) is more than five and one-half miles above sea-level. The *relief* of the land surface is therefore not far from six miles. Compared with the diameter of the earth, even the loftiest mountains are slight elevations, for the height of Mt. Everest above the sea is equal to only $^1/_{1436}$ part of the polar diameter of the earth. On a globe 10 feet in diameter this would correspond to one-twelfth of an inch.

The sea bottom also is uneven, and its relief is a little greater than that of the land. Since the highest points of land are nearly six miles above the sea, and the lowest parts of the sea bottom about six miles below, *the relief of the surface of the solid part of the earth (lithosphere) is almost twelve miles*. If its surface were even, the water of the ocean would cover the whole earth to the depth of about 9,000 feet.

Relief Features of the First Order

Continents and ocean basins. The average elevation of the lands above sea-level is a little less than half a mile, while the average depth of the oceans is about two and one-half miles. Were the height of lands in middle and high latitudes equal to the average depth of the

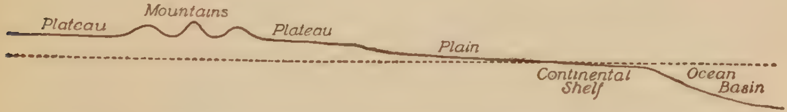


Fig. 14. Diagram to show the distinction between an elevated continental area and an ocean basin. The steep slope (much exaggerated) at the left of the ocean basin is the line of contact between the two, and is the real border of the continental area. The ocean covers the lower part of the continental tract, namely, the *continental shelf*. The diagram also shows the general relation between low mountains, such as the Appalachians, a low plateau, and a coastal plain. The continental shelf is a continuation of the coastal plain.

oceans, much of each continent would be too high and cold to support a dense population. *The continents and the ocean basins are relief features of the first order.*

The oceans have an area (143,000,000 square miles) more than two and one-half times as great as that of the lands (54,000,000 square miles). About most continental borders, the water is shallow (less than 600 feet) for some miles. The bottom beneath this shallow water is the *continental shelf* (Fig. 14). At their sea-ward edges, the continental shelves descend, by rather steep slopes, to the ocean basins. Portions of the continental shelves have been built up from deeper water by the deposition of sediments washed down from the land; other parts are due to the sinking of former land areas; and still others are the result of the wearing back of the land by waves.

Many islands stand on the continental shelves, and represent higher areas whose lower surroundings have sunk, or been cut by waves, below sea-level. In many cases a slight elevation of the continental shelf, or a slight lowering of the sea, would join these islands to the mainland. Thus a rise of 300 feet would transform most of the area of the Baltic and North seas into land, and unite Great Britain with the continent. Such a change would modify greatly conditions in Great Britain. Separation from the continent has freed the United Kingdom from the need of a large standing army, and favored the development of extensive sea interests, which required the maintenance of a large navy to protect them.

Most islands of the ocean outside the continental shelves are volcanic cones, or coral islands associated with them. Their combined area is only about three-fourths that of the state of Illinois.

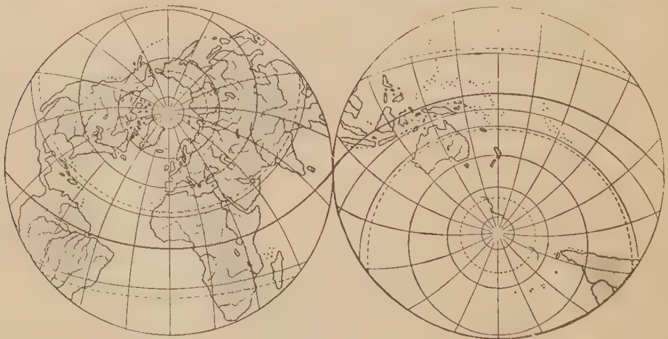


Fig. 15. Land and water hemispheres.

Grouping of the continents. The northern hemisphere contains more than twice as much land as the southern. If the earth be

divided into two hemispheres, one with its center in England and the other in New Zealand (Fig. 15), the first would contain about six-sevenths of all the land, and might be called the *land hemisphere*, while the other would contain only about one-seventh of the land, and might be called the *water hemisphere*. Even in the land hemisphere, however, the water would cover rather more than half the surface, while in the water hemisphere it would cover about fourteen-fifteenths of it. Since the northern hemisphere contains two-thirds of the land, and a still larger proportion of the productive land, it has always supported a vast majority of the human race.

Relief Features of the Second Order

The more strongly marked features of the continents and of the ocean basins are relief features of the *second order*. The continental areas are made up of *plains*, *plateaus*, and *mountains*. Some of their relations are shown in Fig. 14.

Plains. *Plains are the lowlands of the earth.* They may be but a few feet above the sea, or they may be hundreds or thousands of feet above it; but if so high as a thousand feet, they are in most cases far from the sea, and distinctly lower than some of the other lands about them. Plains differ widely among themselves, not only in height, but in position, size, shape of surface, fertility, origin, and in various other ways. Different names are given to various sorts of plains, the names being intended to call attention to some one feature. *Coastal plains* border the sea, and *interior plains* are far from it, or are separated from it by high lands. The plains of the Atlantic and Gulf coasts illustrate the first class, while a large part of the area between the Appalachian Mountains and the Rocky Mountains is a great interior plain (Plate 1).

Plateaus. *Plateaus are highlands with considerable summit areas;* but no great elevation is necessary to make a flattish area of land a plateau. In general, a plateau is so situated as to appear high from at least one side. Thus if a coastal plain rises gradually from the sea to a height of 200 feet, and then rises by a steeper slope to another broad tract of land which stands 200 feet higher (Fig. 14), the upper tract would be called a plateau. The Piedmont Plateau, which lies between the Appalachian Mountains and the Atlantic Coastal Plain, is not very high, but it is enough higher than the Coastal

Plain to be distinctly set off from it. A large part of this plateau is, however, not so high as much of the great interior plain of the continent.

Some plateaus lie between mountains on the one hand and plains on the other, as in the case of the Piedmont Plateau. Others lie between mountains, as the plateaus of central Asia (Fig. 16), Mexico,

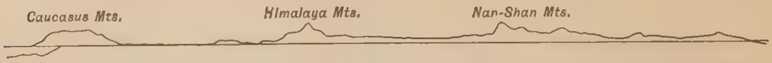


Fig. 16. Section across Asia, showing plateau between the Himalayas and the Nan-Shan Mountains.

Fig. 17. Section across North America, showing plateaus between the mountains in the western part.

and western United States (Fig. 17). Other plateaus rise directly from the sea, as Greenland and parts of Africa. The total area of plateaus is great, though less than that of plains.

Mountains. *Mountains are conspicuously high lands with slight summit areas* (Fig. 18). The tops of the loftiest mountains are between five and six miles above the sea, but most mountains are not half so high. The highest mountains tower above any plateaus, but many mountains are lower than the highest plateaus. Few mountains reach the height of the Plateau of Tibet, 15,000 to 16,000 feet.

Mountains are unlike plateaus of similar elevation in having little area at the top. In the case of mountain *peaks*, this is shown by the name. A mountain *ridge* may be long, but in most cases its top is narrow. Numerous peaks or ranges near together make a mountain *group* or *chain;* but even in great mountain groups there is no large expanse of land at the summit level.

Where mountains rise abruptly to great heights above their surroundings, they are the most impressive and awe-inspiring features of the earth. In not a few cases they rise from low, warm plains to such heights that their summits always are covered with snow. Nowhere else are such extremes of climate found so close together.

Mountains are the third of the three topographic types of the second order, as they appear on the lands of the earth. In this grouping of mountains, only great groups or systems of mountains, such as the Appalachians, the Rockies, the Alps, the Himalayas, and the Andes, are considered.

Most mountain ranges are situated near the edges, rather than in the interiors, of the land masses, and most of the loftier mountain chains are not far from the shores of the greatest ocean. The continental slopes to the Pacific Ocean are therefore shorter and steeper than those to the Atlantic and Arctic oceans. About one-third of the land drains to the Atlantic Ocean, one-sixth to the Arctic, one-seventh to the Pacific, and one-eighth to the Indian. The drainage of the rest of the land (22%) fails to reach the sea, and is lost in dry interior basins.

Fig. 18. Mountains rising conspicuously above a plain. Southern California.

Subordinate Topographic Features

The surfaces of most plains and plateaus are uneven, while the very name of mountain suggests ruggedness. Irregularities of surface consist of elevations, such as *ridges* and *hills*, above the general level, and of depressions, such as *valleys* and *basins* (depressions without outlets), below it. The elevations and the depressions are bordered by *slopes*, which, when very steep, are called *cliffs*. Ridges, hills, valleys, basins, flats, and cliffs affect mountains, plateaus, and plains; but in most cases they are more pronounced in mountains and plateaus than

on plains. These minor unevennesses of surface are *topographic features of the third order*. The key to their history is found in changes now taking place on the land (Chapter XV), or in those which have taken place in recent times.

Comparison of the Continents

The position, form, size, and general relief of the continents are of fundamental importance, since these things determine, in large measure, their fitness for human occupation. *Europe* (Plate IV), the smallest continent except Australia, lies almost entirely in the north temperate zone. It widens rapidly toward the south, so that its east and west extent along the line of the Mediterranean, Black, and Caspian seas is nearly three times that along the Arctic Ocean. No other continent has an outline so irregular. Great arms of the sea extend far inland, modifying climate and helping commerce by bringing most parts of the continent into close contact with the sea. More than half of Europe is less than 600 feet above sea-level, and only one-sixth is over 1,500 feet. Many rivers serve as natural highways into the interior. Some of those in the west are unfrozen throughout the year. Europe has no tropical section, and no dry desert.

Asia (Plate V), the largest of the continents, is nearly 4½ times the size of Europe, and nearly 5½ times as large as the United States. It extends somewhat farther north than Europe, and much nearer the equator. Less than one-fourth of Asia is below 600 feet above the sea, and about one-sixth is above 6,000 feet. The average elevation is nearly three times that of Europe. A central region of high plateaus and mountains receives little rain, and is of slight value to man The longest drainage slopes are toward the Arctic. Because of these things, one-half of Asia is relatively inaccessible. Asia has only about one-third as long a coast-line as Europe *in proportion to its area*. Its great size and relatively compact form make it the continent of climatic extremes. From a physical standpoint Europe and Asia form one continent (called *Eurasia*), but for historical and other reasons they usually are separated.

Australia (Plate VII) is only a little larger than the United States, and is divided almost in halves by the tropic of Capricorn. The coast, though less regular than that of Africa and South America, has few harbors compared to Europe and North America. Because

of its position, size, compactness, and topography, much of Australia is arid (p. 106). Australia is the most isolated of the continents.

About two-thirds of *Africa* (Plate VI) are within the tropics. Broadly speaking, the continent consists of a great plateau, bordered in places by a narrow coastal plain. At the south, the plateau is 3,000 to 5,000 feet above sea-level; at the north, 1,000 to 2,000 feet. Only one-eighth of the land (less than in any other continent) is below an elevation of 600 feet. The rivers descend in rapids or falls to the coastal lowlands. More than one-third of the continent is desert, while other large areas are semi-arid. Africa has the most regular coast of any continent. Europe, with the most irregular outline, has more than six times as much shore-line as Africa, in proportion to its area. Although one of the most ancient civilizations had its seat in Egypt, Africa has remained to our own day the "dark continent." The conditions indicated above have helped greatly to bring this about. The fact that much of the coast is without harbors, and that navigation of even the larger rivers is interrupted near their mouths by falls and rapids, delayed exploration, conquest, and commerce. Both the vast deserts and the dense equatorial forests retarded native progress, and discouraged European settlement.

Like Africa, *South America* (Plate III) is largely within the tropics and is very compact, with few great indentations, peninsulas, or islands. On the other hand, the proportion of desert is much less, and of lowlands much greater. Two-fifths of South America are below 600 feet, and two-thirds under 1,500 feet.

In *North America* (Plate I), as in Europe, most of the land is in middle latitudes. Unlike Europe, North America presents its greatest width to the cold polar seas. North America ranks next to Europe and South America in the relative extent of its lowlands. Nearly one-third of the continent is below 600 feet, and nearly two-thirds below 1,500 feet. The vast interior plain stretching from the Arctic Ocean to the Gulf of Mexico has an unequaled system of navigable waterways. Except Europe, North America has the longest shoreline in proportion to its size. The greatest indentation, the Gulf of Mexico, affects the climate of eastern United States profoundly (p. 85). Except in the far north, most of the indentations have commercial importance.

Questions

1. South America and Africa have few islands about their borders. What does this *suggest* concerning the width of their continental shelves? Does it *prove* anything about the width?

2. Soundings along the eastern coast of the United States have shown that depressions like river valleys extend across the continental shelf from the mouths of various rivers. What do such depressions suggest concerning the history of those parts of the continental shelf where they occur?

3. From the comparison of the continents given on pages 24-25, which ones appear best fitted to contain the most advanced nations? Which ones seem least fitted to do so?

4. Most people live on plains. Would it therefore be better, from the human standpoint, if the earth were without mountains? Reasons?

CHAPTER IV

THE NATURE AND FUNCTIONS OF THE ATMOSPHERE

General Conceptions

Relation to rest of earth. Air is essential to the life of the earth, and to most processes in operation on the earth's surface. It helps to distribute moisture, it makes the extremes of heat and cold less than they would be if it did not exist, and it is a leading factor in the formation of soil. Furthermore, the atmosphere is not merely an envelope of the rest of the earth, for it goes down into the soil and rocks as far as there are holes and cracks, and its constituents are dissolved in the waters of sea and land.

Weight of air. When the atmosphere is still, we are hardly conscious of its existence, but many familiar phenomena show that air is very substantial. Thus wind, which is only air in motion, may be so strong that trees and buildings are blown down by it. A wind blowing 30 miles an hour exerts a force of nearly 60,000 pounds on the side of a house 60 feet long and 20 feet to the eaves. The pressure of still air, that is, its weight, is nearly 15 (14.7) pounds on every square inch of surface at sea-level. In other words, its weight is equal to that of a layer of water completely covering the earth to a depth of 33 feet.

Density. The atmosphere is made up of gases. The particles of which the air is composed are nearer together at low altitudes than at high altitudes. At its bottom, the air is pressed down by all the air above; at the height of 1,000 feet the air is pressed down by all above that level, and so on. Hence the lowest air is under most pressure and is densest. One-half the atmosphere (by weight) lies below a plane about 3.6 miles above sea-level, and three-fourths of it below a plane 6.8 miles above the same level. Nearly three-fourths of the atmosphere lies below the top of the highest mountain. It is partly because the air is less dense at high levels that mountain-climbing is difficult. The body is not accustomed to the lessened pressure, and it causes discomfort.

Height. The actual height of the atmosphere is not known, though something is known about it (Fig. 19).

(1) The greatest altitude reached by any mountain-climber is about 24,000 feet. This shows that the air extends to a height of more than four and one-half miles.

(2) Men have gone up more than six miles in balloons. In some cases, the men in the balloons became unconscious before this height was reached, and in other cases, where oxygen was carried for breathing, the chief discomfort was from cold. Balloons without men have risen eighteen miles. At this height the air is still dense enough to carry the balloon. This shows that the air extends up more than eighteen miles.

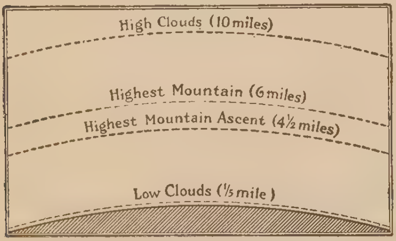


Fig. 19. Diagram to show relative altitudes in the atmosphere.

(3) On almost any clear night "shooting stars" may be seen. Shooting stars, or *meteors*, are small, solid bodies which come into the earth's atmosphere from space outside. They are very cold when they enter the atmosphere, for the temperature of space is very low (probably about —459°F.). In passing through the atmosphere, meteors are heated by friction with the air, and when they get red-hot, they may be seen. The height at which they begin to glow has been calculated in some cases, and found to be, at a maximum, nearly 200 miles above sea-level. This shows that the atmosphere is *much more than 200 miles high*, for the meteors *must have come through the rare, cold, upper air a long distance before becoming red-hot* by friction with it.

From these considerations it appears to be certain that the air extends more than 200 miles above the rest of the earth, but how much more is unknown. Except for a few miles near its bottom, it is, of course, very thin (rare).

Composition

Principal constituents. The composition of the atmosphere is nearly the same at all times and at all places where it has been analyzed. In its lower parts, at least, it is made up chiefly of two gases — (1) *nitrogen*, which makes up about 78 per cent of dry air, and (2)

oxygen, which makes nearly 21 per cent. Some scientists think its composition at great heights may be very different from that below.

Besides these two gases, there are several lesser constituents, two of which, *carbon dioxide* and *water vapor*, are very important. The former makes up about 3/10000 by weight of the whole atmosphere, and its amount is nearly constant from day to day, and from year to year. Water vapor is water in particles too small to be seen. The total amount in the atmosphere is not known to vary much, but the amount varies greatly from place to place, and it varies much from time to time in the same place. Even in the driest deserts the air is never without water vapor. Several other gases exist in the air, but among them *ozone* only is known to be of much importance.

The gases of the air are mixed with one another, and each of them retains its own qualities in the mixture. Oxygen behaves much as if no nitrogen were present, and the nitrogen as if there were no oxygen.

Impurities. The air always contains some gases which are impurities, though they are not necessarily harmful to life. Some such gases arise from the burning and decay of organic matter, others from chemical processes used in manufacturing, and still others from volcanic and other vents in the earth's crust. Although the total amount of gas which enters the air in these ways is small in comparison with the volume of the atmosphere, it would seem very great if stated in terms of weight or volume. For example, it is estimated that at least 1,000,000,000 cubic feet of natural gas escape unused into the air each day in the United States. Quantities of gas are poured into the air, too, from chimneys. The air always contains, as impurities, numerous solid particles, such as dust, and germs or other organic matter. These vary in amount and character from place to place, and from time to time.

Relations of the Different Constituents to Life

Nitrogen. Nitrogen is inactive. Though it enters the lungs with oxygen in breathing, it does not appear to be of direct use to animals. Indeed, its chief function in relation to life is often said to be "to dilute the oxygen." It is important to note, however, that *indirectly* nitrogen is of great importance to both plant and animal life. Most plants use the small quantities of nitrogen compounds in the soil. Nearly all crops, if grown year after year in the same place, take out so much of the nitrogenous matter as to decrease

the fertility of the soil. A few plants, such as clover, alfalfa, peas, and beans, add nitrogen to the soil. Certain bacteria associated with these plants take nitrogen from the air and combine it with other elements, and the plants then store it in their roots, stalks, etc. It is therefore important to grow nitrogen-fixing plants in rotation with other crops, and turn them under the soil.

Oxygen. Oxygen from the air is consumed all the time by animals. Air-breathing animals take it from the air directly, and water-breathing animals take it from the water in which it is dissolved. Oxygen is used by plants also, especially by green plants, and it is used wherever combustion (burning) or decay is going on, for combustion is primarily the union of oxygen with carbon, and decay is very slow combustion. The heat developed by combustion (as of coal) warms houses, and produces steam to run trains, drive machinery, and serve man in many other ways. Oxygen from the air combines with various constituents of rocks to form new compounds, and in so doing helps to form soil (p. 162).

In spite of the fact that oxygen is being consumed all the time, its amount does not appear to grow less from year to year. It must, therefore, be supplied to the air about as fast as it is used up. Plants break up the carbon dioxide of the air into carbon and oxygen, and set some of the oxygen free. This is the greatest source of supply. Small amounts of oxygen also reach the atmosphere from volcanic vents, and in other ways. It will be seen that plants, through their relation to oxygen and nitrogen, play an important part in supplying animals with both these elements.

Carbon dioxide. The carbon dioxide of the air, though a small constituent, is extremely important. It is being made constantly by the burning of all kinds of fuel and by the decay of all organic matter. It is also added to the air by the breathing of animals. Every 1,000,000 human beings breathe out about 2.5 tons per hour. It also comes out of many volcanic vents in great quantities.

From these various sources, carbon dioxide is supplied to the atmosphere rapidly. About three-fourths of common soft coal is carbon. The carbon of a ton of such coal, united with oxygen from the air (3 lbs. of carbon unite with 8 lbs. of oxygen), would make more than 2¾ tons of carbon dioxide, all of which goes into the atmosphere. A ton of hard coal, which contains more carbon, would produce still more carbon dioxide. Nearly a billion tons of coal are mined each year, and most of this is burned. When all sources of carbon dioxide are considered, it seems safe to say that carbon dioxide is being supplied to the atmosphere at the rate of about 75 tons per second.

Because of its close relations to combustion, respiration, and decay, the amount of carbon dioxide in the air of cities is greater than in the open country. The amount in the air of London occasionally becomes five times the normal quantity, while in badly ventilated schoolrooms, theaters, and workshops, it is sometimes ten times the normal amount. The conditions which increase the amounts of carbon dioxide in city air usually increase the amounts of various other harmful gases. Such conditions are injurious to health. The widespread movement to "purify city air," largely by doing away with smoke, is an attempt to remedy these conditions.

In spite of constant additions, the amount of carbon dioxide in the air does not increase permanently enough to be noted. This gas, therefore, must be taken out of the atmosphere about as rapidly as it comes in. It is taken from the air chiefly (1) by green plants, of which it is the main food, and (2) by uniting with mineral matter in the solid part of the earth. It supports not only most plants, but indirectly most animals, for the latter feed on vegetation, or on other animals that live on plants. By uniting with mineral matter it helps to form soil.

The carbon dioxide of the air has still other important functions. The earth is radiating heat into space all the time, somewhat as a hot stove radiates heat into its surroundings, and carbon dioxide has the power of holding much of this heat. It therefore serves as a blanket to hold in the heat of the earth, and, thin as the blanket is, it is more effective, in this respect, than the denser blanket of oxygen and nitrogen. If it were thicker, the temperature would be still higher. It is thought possible that at certain times in the distant past, as when magnolias grew in Greenland, the amount of carbon dioxide in the air may have been greater than now; and that at other times, when the climate was cold in low latitudes, the amount may have been much less than now.

Water vapor. The water vapor in the atmosphere is a variable quantity. It is all the time entering the atmosphere by evaporation, and it is all the time being condensed and precipitated from the atmosphere as rain, snow, etc., to be again evaporated, condensed, and precipitated. The larger part of both water vapor and carbon dioxide is in the lower part of the atmosphere. Like much of the carbon dioxide, the water vapor is making continuous rounds. Its precipitation supplies the water for wells, the flow of springs, the maintenance of lakes, streams, and glaciers, and for the life of plants

and animals. The bodies of animals, including human beings, are about four-fifths water. The tissues of annual plants are three-fourths water; of perennials, nearly half. To produce a bushel of corn, from 10 to 20 tons of water are required.

The amount of water vapor which the atmosphere is capable of containing at any time depends on temperature; but other things, such as the available supply, help to determine the amount which there is in the air in any one place. Like the carbon dioxide, the water vapor of the air helps to keep the earth warm.

Dust. All solid particles held in the air are dust. They are not ordinarily seen except on dry, windy days, but dust from the air is constantly settling everywhere, indoors and out, whenever the air is dry. Dust may be seen readily indoors if a room is darkened and light allowed to enter through a narrow crack or small hole. Even air which appears clear may in this way be seen to contain countless particles of solid matter. The amount of dust is sometimes very great, as over cities and in dry and windy regions. During the fogs of February, 1891, it was estimated that the amount of dust deposited on roofs in and near London was six tons per square mile. Dust-polluted air is believed to favor diseases of the lungs, like tuberculosis.

Some years ago a method was devised for counting the dust particles in a given volume of air. The result showed that in the air of great cities there are hundreds of thousands of dust particles in each cubic centimeter of air (a cubic centimeter is less than $^1/_{16}$ of a cubic inch); and that even in the pure air of the country, far from towns and factories, there are hundreds of motes per cubic centimeter.

Like carbon dioxide and water vapor, most of the dust is found below an altitude of 10,000 feet. Its relative absence at high altitudes increases the intensity of the sunshine there by day, and helps to bring about low temperatures at night.

Dust particles in the atmosphere are important in several other ways. They scatter the light of the sun in such a way as to illuminate the whole atmosphere. Without dust in the air, all shady places would be in darkness. The sun would appear, probably in dazzling brilliance, shining from a black sky in which the stars would be visible even in the daytime. The blue color of the sky and the sunset and sunrise tints are influenced by the dust in the atmosphere. Dust particles also serve as centers about which water vapor condenses.

Questions

1. State the conditions (all of them) which would tend to make the country air dusty at a given point in northern United States.

2. What conditions favor an increase in the amount of dust in the air of cities in summer? In winter?

3. Compare and contrast the purity of the air (1) over oceans and over lands; (2) in dry and in moist regions; and (3) at high and at low altitudes.

4. Would you expect the average amount of carbon dioxide to be greater in the air of cities or of the open country? Why? What processes tend to equalize the amount over country and cities?

5. Give at least three reasons why the amount of carbon dioxide in the air (especially of great cities) tends to vary in amount between summer and winter.

6. Why do people accustomed to low altitudes breathe very much faster in high altitudes?

7. Indicate various ways in which the extreme elasticity of the air favors human activities.

CHAPTER V

CLIMATIC FACTORS: TEMPERATURE

General Considerations

Besides the composition of the atmosphere, various other things connected with it are of great importance to life. The things which make up climate (*climatic factors*) are especially important. The chief climatic factors are (1) *temperature*, (2) *moisture*, and (3) *air movements*, or wind.

Importance of heat. Were it not for the effect of the atmosphere on temperature, life could not endure the heat of day or the cold of night, and the earth would be a desolate, lifeless waste. The temperature which most concerns land life is the temperature of the air in which it lives. The air is warmed chiefly by the sun. The heating power of the sun is proved by the fact that days are warmer than nights, and that sunny days are warmer than cloudy ones. The rare exceptions to these general facts need not be considered now.

Measurement of heat. Variations of temperature from time to time and from place to place are so important that it is necessary to have some easy way of measuring and recording them. Temperature is measured by the *thermometer*, which consists of a glass tube of uniform diameter, except for a bulb at the lower end. The bulb and the lower part of the tube are filled with some liquid, generally mercury, and this is heated until it boils. The boiling mercury fills the tube and expels all air, and while it is boiling the tube is sealed, the heat being withdrawn at the same moment. On cooling, the mercury contracts and fills the lower part of the tube only. Whenever the temperature rises, the mercury expands and rises in the tube, and when the temperature falls, the mercury contracts and sinks. The amount of rise or fall of the mercury shows the amount of change of temperature.

A scale is marked on the tube so that the temperature may be read from it. Two scales are in common use — the *Fahrenheit* (F.) and the *Centigrade* (C.). On the Fahrenheit scale the temperature of boiling water (at sea-level under normal pressure) is marked 212°; on the Centigrade scale, 100° (Fig. 20). The temperature of melting ice (*freezing point*) is marked 32° on the former scale, and 0° (*zero*) on the latter. Between the freezing and the boiling point on the Fahrenheit scale there are 180 degrees, and on the Centigrade scale 100 degrees. It follows that 1° C. is equal to $1\frac{4}{5}$° F. Zero on the Fahrenheit scale is 32° below the freezing point, and 20° below zero Fahrenheit (written — 20° F.) means 52° (32° + 20°)

below the freezing point. The Centigrade scale is simpler than the Fahrenheit, and is used generally in scientific work and in most European countries.

We often have occasion to use the temperature of a given place at a given time, as that of New York at noon on July 4th; but we also have occasion to use the records of temperature in other ways. From a sufficient number of temperature records, spread properly over a year, an average temperature for that year may be obtained. Similarly, averages for shorter periods, as seasons, months, and days, are possible, called average *seasonal*, *monthly*, and *daily* temperatures. The average temperature of one year for a given place is, as a rule, somewhat different from that of the preceding or following year. The average temperature for a goodly number of years gives its *mean annual temperature*. Similarly, it is necessary to take the averages for many Januarys to get the *mean monthly temperature* for that month. The highest temperature during any period is its *maximum temperature* and the lowest, its *minimum temperature*.

Fig. 20. Diagram to represent Fahrenheit and Centigrade scales.

Sun heating: insolation. The northern and southern hemispheres receive the same amount of heat from the sun each year, but, because of the inclination of the earth's axis, they do not receive the same amounts at the same seasons. Both receive the same amounts of heat per day only at the times of equinox. The amount of heat received by the surface of land and water is far less than the amount coming to the top of the atmosphere, for much is absorbed in passing throug the air.

(1) Other things being equal, any part of the earth should get most heat per day when the sun shines there the greatest number of hours. During a part of the summer of the northern hemisphere, latitudes above 66½° have sunshine continuously (except for clouds) for more than 24 hours. So far as hours of sunshine are concerned, therefore, these latitudes should then receive more heat per day than other parts of the earth. If there were no atmosphere, the surface of the earth at the North Pole would receive, on the 21st of June, about one-third more heat during 24 hours than the surface of an equal area at the equator. But the amount of heat which reaches the *bottom of the air* at the pole on the 21st of June is much less than that received at the bottom of the atmosphere at the equator.

(2) Other things being equal, the surface of the land or water gets most heat where the sun's rays are most nearly vertical, because (a) the rays are there most concentrated, and (b) they pass through a less thickness of the air. This is shown by Fig. 21. A given bundle of rays, 1, falling vertically on the surface, is distributed over a given area, while an equal bundle of rays, 2, falling obliquely on the surface, is spread over a greater area, and therefore heats each part less. The rays oblique to the surface, 2, have passed through a greater thickness of air, and more of their heat has been absorbed by it before they reach the surface of the land or water. These facts help to explain why the surface at the poles does not get warmer than an equal area at the equator, even with months of continuous sunshine at the former places, and but 12 hours at a time at the latter. The snow and ice of polar regions prevent them from getting warm, even during the months when much heat is received (p. 37).

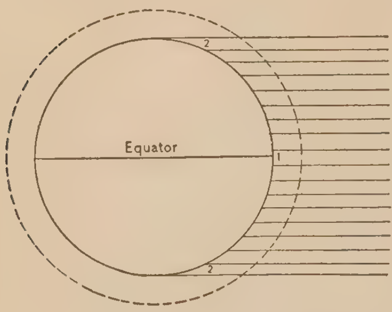


Fig. 21. Diagram to illustrate the unequal heating at the bottom of the atmosphere, due to the angle at which the rays of the sun reach the surface of the earth. The dotted line may be taken to represent the outer limit of the atmosphere.

The angle at which the sun's rays reach the earth varies from place to place, and from time to time at the same place, because of the inclination of the earth's axis. This is illustrated by Figs. 8 and 9, which have been explained.

Distribution of insolation. From Fig. 10, which has been studied, we see that when the sun's rays come to the earth from the direction *W* (perpendicular 23½° south of the equator), they are more oblique than at any other time in the northern hemisphere, and less oblique than at any other time in the southern hemisphere. At the same time the days are longer in the southern hemisphere than in the northern. Hence there are two reasons why the southern hemisphere receives more heat than the northern at this season, namely (1) more nearly vertical rays, and (2) more hours of sunshine.

After the time (winter solstice, December 22d) when the sun's rays are vertical at 23½° S., they become perpendicular to the sur-

face in latitudes farther and farther north, and on March 21st they are vertical at the equator. Days and nights are then equal everywhere, because all parallels are cut into two equal parts by the circle of illumination (p. 12), and the sun's rays are equally oblique in corresponding latitudes north and south of the equator. Any latitude in one hemisphere is then receiving the same amount of heat as the corresponding latitude in the other hemisphere. This condition would be permanent if the axis of the earth were not inclined.

After March 21st, the sun continues its apparent journey northward until June 21st, when its rays are vertical at the tropic of Cancer, 23½° N. The days of the northern hemisphere are then longest and the nights shortest, and the rays of the sun are less oblique in this hemisphere than at any other time. At this time, therefore, the northern hemisphere is being heated more than at any other.

From June 21st to December 22d, the sun appears to move so that its rays become vertical farther and farther south, and the preceding changes are reversed.

The latitudes where the sun's rays fall vertically range from the tropic of Cancer to the tropic of Capricorn; and the sun's rays are, on the average, least oblique between these limits. This is why low latitudes are, on the whole, warmer than high latitudes.

The density of the atmosphere also affects the amount and intensity of the insolation received by the surface of the earth. On mountains the less density of the air means more intense sunlight, and a greater amount of heat per unit of land surface, than is received at sea-level (p. 39). One effect of this is seen in the rapid growth of plants on mountains in early summer.

Distribution of temperature. The temperature of one place is not necessarily higher than that of another because it receives more heat. The region about the North Pole does not get very warm, even when it receives much heat, because much of the heat received is used in melting ice and in warming ice-cold water, which is warmed very slowly, and flows away as soon as the heating is well begun. Mountain tops are also generally cold in spite of the intensity of insolation there.

After the heat from the sun has been received by the earth, it is re-distributed to some extent, with the general result that the parts which get more by insolation share their heat with the parts which

get less. The distribution of actual temperature, therefore, differs much from the simple distribution which insolation would give.

There are three ways in which the air receives, loses, and transfers heat. These are *radiation*, *conduction*, and *convection*.

(1) *Radiation. The sun always radiates heat,* and the surface which its rays strike is warmed by absorption of the radiated heat. A body need not be glowing hot, like the sun, or like fire, to radiate heat. The radiators in our houses radiate heat when they contain hot water or steam. The body which radiates heat is itself cooled. Thus hot iron soon cools in the air, because it radiates its heat. The land warmed by the absorption of heat radiated from the sun during the day is cooled by the radiation of its heat at night. The absorption of heat by day and its loss by night give variations of temperature between day and night. If the day is long and the night short, absorption of heat from the sun by day exceeds radiation by night, and the land tends to become warmer, as in spring and early summer. If the day is short and the night long, radiation of heat will be greater than absorption, and the land will become colder, as in autumn and early winter.

(2) *Conduction.* If one end of an iron poker is put in the fire, the other end becomes hot. The heat passes from one end to the other. This method of passing heat along is *conduction.* Any cold body in contact with a hot body is warmed by conduction. The hand is warmed by conduction when placed on anything which feels warm; it is cooled by conduction when placed on something which feels cool. The bottom of the air is warmed by contact with the land (that is, by conduction) wherever the temperature of the land is higher than that of the air. Conduction from the land to the bottom air has an important effect on the temperature of the air just above the ground.

(3) *Convection.* When a kettle of water is placed on a hot stove, the water in the bottom is heated by conduction, that is, by contact with the hot kettle. The heating of the water causes it to expand, and when the water in the bottom of the kettle expands, it becomes lighter than the water above. The heavier water above sinks and pushes the lighter water below up to the top. This movement is *convection.* Another illustration of convection is afforded by stoves, fireplaces, and furnaces. A thin sheet of light paper may be held up for a moment by the rising air over a hot stove, or even carried up if the convection current is strong enough. Again, as the air in a chimney is heated, it expands and becomes less dense than the air

about it. The cooler, denser air about the base of the chimney or stove crowds in below the expanded air in the chimney, and pushes it up out of the chimney. Since the air entering the chimney from below is being heated and expanded all the time, the up-draught continues as long as there is fire. Every draught from a chimney is an example of convection.

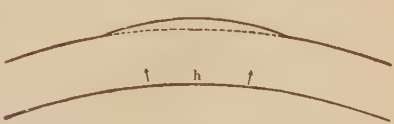


Fig. 22. The first rise of air, as a result of heating, is due to the expansion of the part heated.

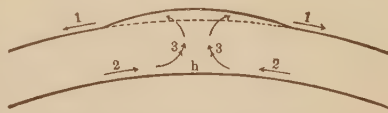


Fig. 23. The permanent heating of the air over a region gives rise to permanent convection currents.

When the surface of the land is warmed by the absorption of heat from the sun, it warms the air above both by conduction and by radiation. The lands of low latitudes are heated more than others. The heated air over the heated land expands. If the air in a given region were expanded as shown in Fig 22, the air at the top of the expanded column would flow away, much as water would under similar conditions. After this takes place, the amount of air at the base of the column *h* will be less than the amount at the same level outside the heated area, and air from outside the heated column will flow in. This inflow will push up the column of expanded air, and further overflow above will cause further inflow below. If the heating continues, a permanent convection current is established in the heated area (Fig. 23). Such movements of air are important not only in distributing temperature, but also in causing winds, clouds, and storms.

The atmosphere is heated (1) by the absorption of the sun's rays as they come through it, (2) by the absorption of heat radiated from land and water, and (3) by conduction from warm land or water to the lower air. The amount of heat absorbed by air from the direct rays of the sun depends on the distance the rays travel in it, that is, on the obliquity of the sun's rays (Fig. 21). When the sun is vertical at the equator, its rays pass through about twice as much atmosphere in latitude 60°, and about ten times as much in latitude 85°, as they do in latitude 0°. The amount of absorption of sun-heat by the air, therefore, varies with latitude. About half of it is absorbed by the air at the equator, and about four-fifths at the poles, as compared

with the total amount which would reach the earth in those latitudes if there were no atmosphere. In general, the amount of heat absorbed by the atmosphere is more than 50 per cent of the total amount coming to the earth from the sun.

The heat radiated into the air from below is absorbed by the air much more readily than that coming from the sun directly. The lower air consequently is heated by radiation from below more than by direct insolation.

After heat is received from the sun, therefore, it is re-distributed by radiation, conduction, and convection. Movements of air (winds) and movements of water (especially ocean currents) also distribute heat. Without these movements of air and water, the average temperature of the equator would be much higher than now, and that of the poles much lower. These changes would be destructive to many forms of life.

Temperature of land and water. Land is heated by insolation four or five times as fast as water, for several reasons:

(1) A given amount of heat raises the temperature of soil and rock more than that of water.

(2) Water is a good *reflector*, while land is not; the latter, therefore, absorbs a larger proportion of the heat of the sun's rays.

The amount of heat reflected from a water surface increases with increasing obliqueness of the sun's rays. At the equator, 40 per cent of the insolation goes into heating the water; in latitude 60°, less than 5 per cent. A familiar result of the reflection of heat from water appears in the intensity of sun-burn received on water. Snow-covered land and bare white sand reflect heat much as water does.

(3) Land radiates heat more readily than water does.

(4) Convection movements take place in water as soon as its surface is heated. This prevents excessive heating at any one point. The land, on the other hand, is without movements of convection.

(5) There is more evaporation from a water surface than from land, other conditions being the same, and evaporation cools the surface from which it takes place. A wet soil, receiving the same amount of the sun's rays, remains cooler than a dry soil. The hot sand of the desert is an example of this effect on the warming of the land.

(6) Light and heat penetrate water, but not soil and rock to any great extent. The heat of insolation is therefore distributed through a greater thickness of water than of soil. Being confined to the surface of the soil, the temperature of the latter is made higher.

Since the temperature of air tends to be the same as that of the surface on which it lies, the presence of land or water is an important factor in determining the temperature of the air above.

Seasons

In Middle Latitudes

In middle latitudes, the seasons are four — spring, summer, autumn, and winter. Each season has characteristics of its own, but each grades into the one which follows.

In the United States, March, April, and May are commonly called the spring months; June, July, and August the summer months; September, October, and November the autumn months; and December, January, and February the winter months. In the southern hemisphere, spring comes in September, October, and November; summer in December, January, and February, and so on. The vernal equinox of the northern hemisphere is the autumnal equinox of the southern, and the summer solstice of the northern is the winter solstice of the southern. The definition of the seasons given above is based on temperature, the warmest three months being summer, and the coldest three, winter. The seasons are sometimes defined in a different way. Thus spring is sometimes regarded as the time between the vernal equinox and the summer solstice; summer the time from the summer solstice to the autumnal equinox, and so on.

Summer and winter temperatures. The summer heat of middle latitudes is due (1) to the high altitude of the midday sun above the horizon, giving less oblique rays with a shorter path through the atmosphere, and (2) to the long days and short nights. More heat is received during the long day than is lost during the short night. The reverse of these conditions accounts for the cold of winter, though during the winter of the northern hemisphere the earth is 3,000,000 miles nearer the sun than in summer.

A consideration of Figs. 3 and 9 will make it clear why the seasons are reversed in the two hemispheres. One result of this difference of seasons in opposite hemispheres at the same time is that crops in the middle latitudes of the southern hemisphere are harvested in our late winter and early spring, when the northern supplies of certain things are running low. Hence there is important trade between the two hemispheres, places in each hemisphere being benefited because their crops ripen in the cold season of the other.

Warmest and coldest months. Since the northern hemisphere receives most heat at the time of summer solstice, and least at the time of winter solstice, it would seem at first that these dates, respectively, should be the times of greatest heat and cold; but this is not the

case. Again, since corresponding latitudes in the two hemispheres are being heated equally at the time of the equinoxes, it would seem, at first, that corresponding latitudes in the two hemispheres should have the same temperature at these times; but this, again, is not the case. In our own latitudes, for example, March 21st (vernal equinox) is much colder than September 22d (autumnal equinox).

The explanation of these conditions is found in the fact that the temperature of any given place at any given time does not depend entirely on the amount of heat received from the sun at that time. In our latitudes, the soil, rocks, lakes, and rivers receive more heat during the long days of summer than is lost during the short nights. At the end of summer, therefore, heat has been stored up in them. At this time of year, the northern hemisphere has a temperature higher than that which it would have if it depended entirely on the heat received from the sun each day. On the other hand, the temperature at the time of early spring is lower than that which the daily heating would seem to produce, because the cold of the winter just past has not been altogether overcome. Some of the snow and some of the ice of lakes, ponds, streams, and soils, in middle and high latitudes, is still unmelted. The snow and ice keep the lower part of the air cool.

For similar reasons, the summer solstice is not the hottest time of year. The time of greatest heat lags behind the time of greatest heating. In middle latitudes the lag is about a month; but it is more over oceans than over lands, because land is heated and cooled more readily than water. For this reason places near bodies of water usually have later and colder springs than places not so situated. Under such conditions, April in the northern hemisphere may be as cold as November. In the same way, the time of greatest cold does not come till after the time of least heating.

In Tropical Latitudes

The seasons in low latitudes are unlike our own. At the equator, the sun's rays are vertical twice each year — at the times of the equinoxes. Twice a year, too, the sun's rays are vertical $23\frac{1}{2}°$ from the equator, once to the north and once to the south. The equator, therefore, has two seasons, occurring at the time of our spring and autumn, which are somewhat warmer than two other seasons occurring at the time of our summer and winter. The variations in temperature are much less than in middle latitudes, for the length

of day and night never varies at the equator, and does not vary much in any part of the tropics. The angle of the sun's rays, too, varies less than with us. At the equator, therefore, there are four divisions of the year, but their differences of temperature are slight.

Toward the margins of the tropical zone, the variations of temperature are greater than at the equator, but far less than in middle latitudes. In much of the tropical zone, wet seasons alternate with dry ones, and in such places, differences in moisture are more important than differences in temperature.

In High Latitudes

In high latitudes, the seasons are still different. About latitude 60°, for example, the differences in the seasons are similar to those of the central part of the United States, except that they are greater, because of the greater variation in the length of day and night. In latitude 63°, the longest day of summer and the longest night of winter are about 20 hours each, as compared with a little over 15 hours in latitude 40°. The long nights of winter in latitude 63° mean much lower temperatures than in latitude 40° at that season. On the other hand, the long hours of sunshine in summer make it possible, in favored localities, to grow crops as far north as latitude 60°, even where it is only four months from snow to snow.

In latitude 75° N., which may be taken as typical of polar regions, there are four natural divisions of the year, one (summer) when daylight is continuous, one (winter) when darkness is continuous, one (spring) when there is alternating day and night, with the days lengthening, and one (autumn) when there is alternating day and night, with the nights lengthening. The lengths of the seasons defined in this way are not the same.

There is a common notion that in polar regions there is a day of six months and a night of six months each year, but this is not correct. There is a six-month day and a six-month night *at the poles only*. In latitude 78°, about half way between the pole and the polar circle, there is continuous daylight and continuous darkness for periods of about four months each. In latitude 70° the periods of continuous darkness and of continuous light are two months each, and so on down to 24 hours at the polar circle.

Though the name summer may be applied to one part of the year in high latitudes, places north of latitude 60°–65° are not warm enough in summer for the growth of cereal crops. Vegetation is confined to grasses, stunted shrubs, lichens, and mosses.

Relation of Temperature and Altitude

High altitudes are colder than low levels in the same region, (1) because the air is thinner, and (2) because it contains less water vapor, carbon dioxide, and dust. For these reasons it absorbs less heat from the direct rays of the sun, and less of that radiated from below. The temperature of the air on top of a mountain may be much lower than the temperature of the air at its base, in spite of the fact that insolation is much greater in the former position.

The average decrease of temperature is about 1° F. for each 330 feet of rise, or 16° for each mile, for the altitudes where observations have been taken. One mile of ascent, therefore, means about the same decrease of temperature as a journey of 1,000 miles (about 15° of latitude) toward the poles. Tropical highlands, like those of Mexico or Bolivia, in latitudes 18° to 19° N. and S. respectively, are cooler than some places at sea-level in middle latitudes. For this reason, some countries in the tropics can produce not only tropical crops, but also those characteristic of other regions, and by living at the higher elevations, the people may escape the uncomfortable heat of tropical lowlands. In middle latitudes also vegetation varies with the altitude. Thus, in the low mountains of Pennsylvania, the ridges bear coniferous trees (pines, etc.), sugar maples, and similar types, while the valleys between have the honey locust, gum, and walnut, which need a warmer climate.

The low temperatures of certain mountains and high plateaus of the middle zones do not favor dense populations. On the other hand, the cool climates of various high lands in the tropics have favored white settlements. During the hot summer months the capital of India was transferred each year from Calcutta (the capital until 1911), near sea-level, to Simla in the Himalayas, at an elevation of 7,000 feet. Certain elevated places in the Philippines, like Baguio, the summer capital, will have increasing importance as health and pleasure resorts during the hot period.

The difference in vegetation and in human conditions between the sunny and shady slopes of mountains is striking in many cases. Thus at a place near Zermatt, in the Alps, barley and rye are grown on a sunny southern slope 6,900 feet above sea-level, while a few hundred yards away, northern slopes, even below the level of the grain fields, have arctic-alpine vegetation and snow-banks. In some of the valleys in the Alps, most of the people live on the sunny slopes.

Where mountains are covered by snow throughout the year, *their surfaces are never warmed above a temperature of 32° F.*, the melting temperature of snow. All the heat received beyond that necessary to raise them to this temperature is spent in melting and evaporating snow, not in raising the temperature of its surface. Yet in spite of the freezing temperature, travellers over the snow-fields may be sun-burned, as if exposed to midsummer sun at lower altitudes. Part of this effect is due to the greater intensity of insolation at higher altitudes, and part of it to the fact that snow reflects heat much as water does (p. 40).

Representation of Temperature on Maps

It is important to have some means by which temperatures in different places and at different times may be studied readily. For large areas it is most convenient to have the temperatures shown on maps. Maps showing temperatures are *thermal maps*. On such maps temperatures and their distribution commonly are shown by lines, each of which connects points having the same temperature. Such lines are *isotherms*, and maps showing isotherms are *isothermal maps*. A line connecting places having the same average annual temperature is an *annual isotherm*. Lines connecting places of the same average seasonal or monthly temperature are *seasonal* or *monthly isotherms*.

Fig. 24 shows annual isotherms. The map does not give exact average temperatures for places between the lines, but temperatures for such places can be estimated from the map. At the extreme north there is the isotherm of 0° F., which barely touches North America. The average annual temperature of places on this line is 0° F. The isotherm of 10° F. lies south of the isotherm of 0° F. The average temperature of places between these two lines is more than 0°, and less than 10°. South of the isotherm of 10° follow, in order, the isotherms of 30°, 50°, 60°, and 70°. The lowest isotherm shown on the chart in the southern hemisphere is that of 30°, lying south of all lands except Antarctica. The latitude of this isotherm corresponds nearly to the latitude of the isotherm of 30° in the northern hemisphere. Next toward the equator from the southern isotherm of 30° is the isotherm of 50°, followed by those of 60° and 70°. Thus the map shows a relation between latitude and annual temperatures, the highest temperatures being near the equator.

Annual isotherms do not show all we may want to know about the temperature conditions of a place. An annual isotherm of 50° F., for example, does not tell us whether the temperature is about 50° F.

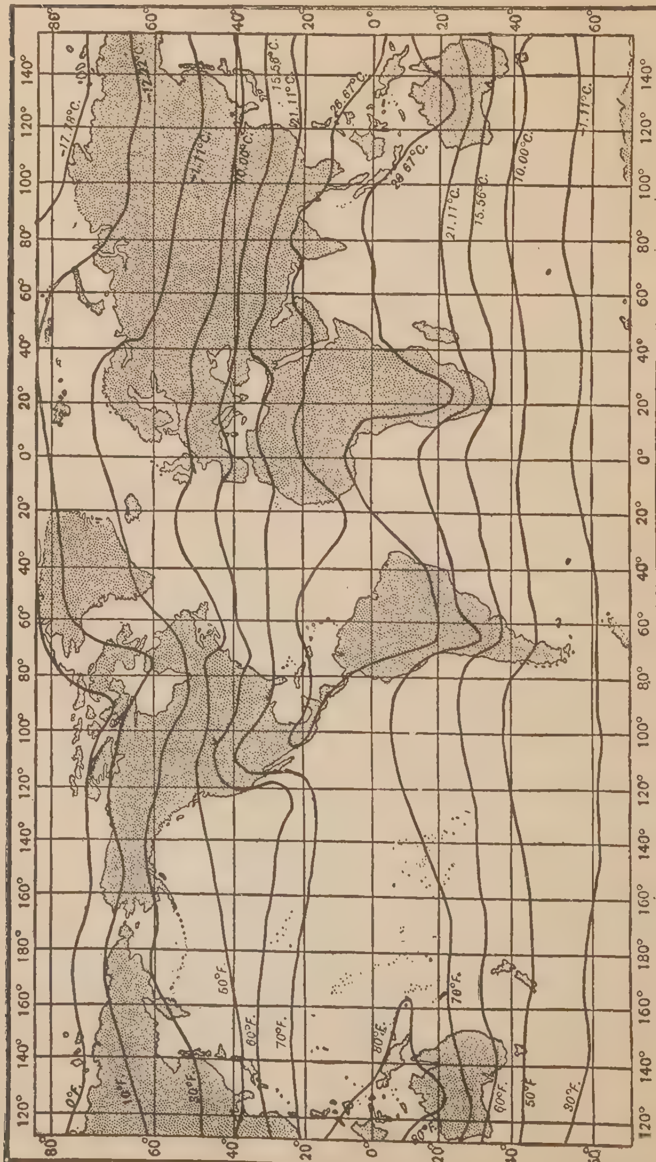


Fig. 24. Average annual temperatures for the world. (After Buchan.)

all the time, or whether it is 80° F. in summer and 20° in winter. Seasonal and monthly isotherms are of more significance in connection with crops, and give a better idea of the temperature conditions of a place. This may be illustrated by the fact that the annual isotherm of New York is about the same as that of southern England, while the summer isotherm of the former place is more than 10° warmer than that of the latter. Since summer temperatures are the most important for crops and for many human activities, the difference of more than 10° in that season is enough to make New York and southeastern England quite unlike in many respects. Again, San Francisco and St. Louis have the same mean annual temperature; but the January average is only 10° lower than the July average at San Francisco, while it is 45° lower at St. Louis. *Range of temperature* is, therefore, important. The annual range of temperature for Quito, Ecuador, is 1° F.; that is, the warmest month is only about 1° warmer than the coolest. For San Diego, Cal., the range is 16° F.; for St. Paul, Minn., 60°; for Yakutsk, northeastern Siberia, 100°.

Fig. 25 shows the isotherms for January. On this chart corresponding isotherms are farther south than on the chart of annual isotherms. Thus the isotherm of 0° F. (— 17.78° C.) in the northern hemisphere runs through central Asia, instead of lying north of it, and the isotherm of 60° is everywhere south of latitude 40°, instead of being partly north of it, as in Fig. 24. At this time of the year, the sun is shining vertically south of the equator. This seems to be a sufficient reason for the change.

Fig. 26 shows the isotherms for July. All isotherms are farther north than the corresponding ones on either of the other charts. Thus the isotherm of 50° in the northern hemisphere is about where the isotherm of 20° was in January (Fig. 25).

Comparing Figs. 25 and 26, it is seen that the difference of temperature between January and July is much greater in high latitudes than in low. Thus in the southern part of Hudson Bay there is 70° difference between January and July; at Lake Erie, about 45°; in Florida, about 20°; and near the equator in South America, less than 10°. The same charts show that the difference is greater in the interiors of continents than on coasts or over the sea in the same latitude. Thus in the interior of North America, west of Hudson Bay, the difference is about 80°, while on the coast of Alaska it is only about 30°. These conditions bear out the conclusions already reached, (1) that the difference in the amounts of heat received at

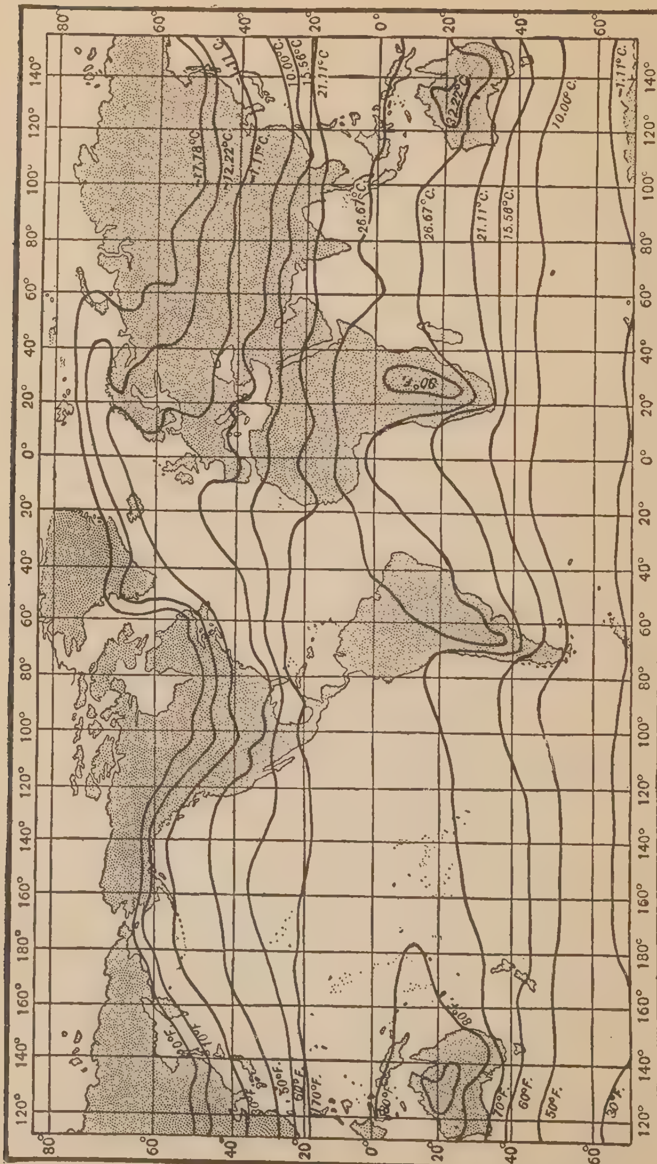


Fig. 25. Isothermal chart for January. (After Buchan.)

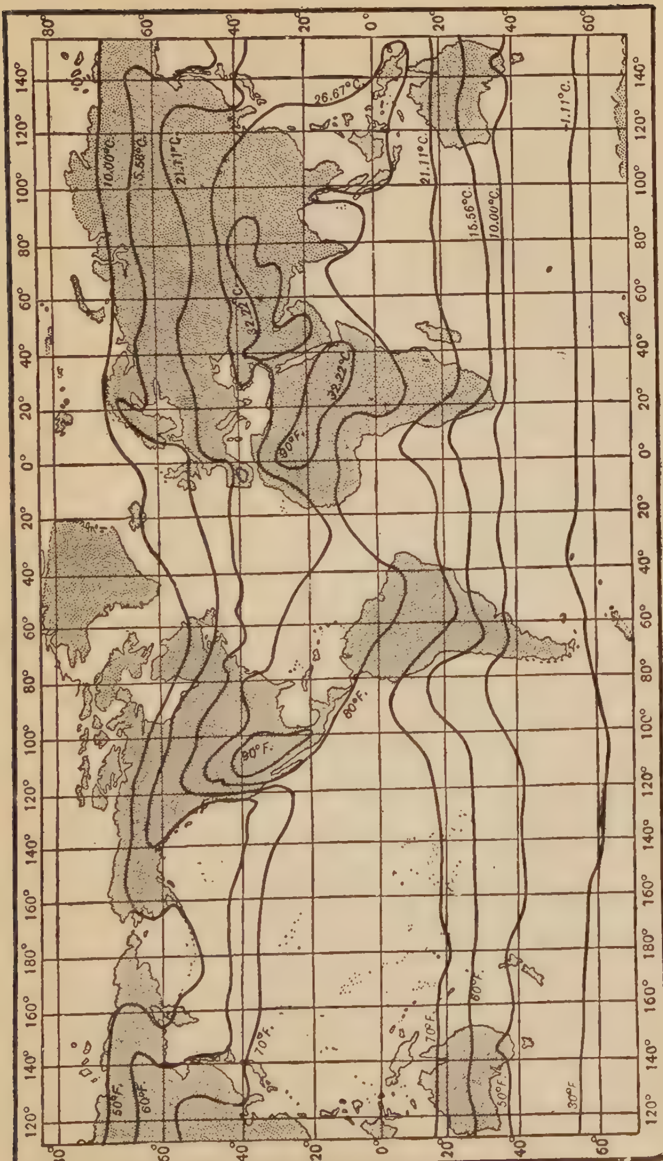


Fig. 26. Isothermal chart for July. (After Buchan.)

different seasons is greater in high latitudes than in low latitudes, and (2) that land heats and cools more readily than water.

The courses of isotherms. (1) The isotherms are roughly parallel to the parallels of latitude. Some of them are very irregular, it is true, but the east-west direction is the most common one. This shows some relation between the courses of isotherms and *latitude;* but since the isotherms do not follow the parallels exactly, it is clear that latitude is not the only thing which determines their position.

(2) Figs. 25 and 26 show that the isotherms are least crooked where there is little land, and most crooked where there is much land. This suggests that the *land and water* have something to do with their positions. There are various irregularities in the isotherms on land that do not appear on the sea. Thus, on the January chart, there is an area in South Africa, and another in Australia, surrounded by the isotherm of 90°, and in July there are similar areas in North America, northern Africa, and southern Asia. All of these areas are on land. These facts tend to confirm the conclusion that the sea and the land influence the position of the isotherms.

Following this idea further, it is seen that some of the isotherms of January bend somewhat abruptly toward the equator in passing from water to land, and toward the pole in passing from land to water. Thus the isotherm of 30° in the northern hemisphere turns to the south where it reaches North America, and again on the coast of Europe. In the southern hemisphere, the isotherms of 80° and 70° make abrupt turns at the west coast of Africa, and the isotherm of 70° near the west coast of South America. These bends at the coasts give further support to the conclusion that the distribution of land and water has something to do with the position of isotherms.

It has been noted already (p. 40) that the land is heated and cooled more readily than the sea, and is therefore colder in winter and warmer in summer. The January isotherm of 30° in the northern hemisphere bends toward the equator in crossing the northern continents, because the land is cooler than the water in the same latitude, at this time of year. In the southern hemisphere, where it is summer, the isotherms bend toward the pole on reaching the land, because the land is warmer than the sea in the same latitude.

The chart of the July isotherms leads to the same conclusion. On this chart, isotherms crossing the northern continents bend poleward on the land, while those crossing the southern continents bend equatorward. This is the season when the lands of the northern

hemisphere are warmer than the seas of the same latitude, and when the lands of the southern hemisphere are cooler than the seas.

The irregularities of the isotherms of the northern hemisphere in July are much greater than those of the southern hemisphere in January (summer in the southern hemisphere). This is probably because there is much more land in the northern hemisphere than in the southern, and the larger land areas have a greater effect on the isotherms than the smaller ones.

(3) There are some features of the isothermal lines which are not explained by latitude, or by the distribution of continents and oceans. Thus the bends of the isotherms are not as pronounced on the east sides of the continents as on the west. This is shown by Figs. 25 and 26. Again, traced eastward, the January isotherm of 50° bends southward near the west coast of North America more sharply *on the land*, while on the eastern side of the continent it bends northward *on the sea*, not on the land. Such peculiarities may be explained by the *winds*. The prevailing winds in the middle latitudes of North America are from the west. These winds tend to carry the temperature of the sea (warmer in winter) over to the land on the western side of the continent (Fig. 25), and the temperature of the land (cooler in winter) over to the sea, on its eastern side. This explains the bends of the isotherm of 50°, for example, near the coasts in the northern hemisphere in January. Coastal lands on the western sides of continents in middle latitudes tend to have temperatures like those of the neighboring ocean.

(4) The great bend in the January isotherm of 30° in the North Atlantic is due to a northeastward movement of warm ocean water in the direction of the pronounced loop of the isotherm. *Ocean currents* are therefore a fourth cause of the irregularities of isotherms. The amount of heat carried northward by the ocean currents of the Atlantic and Pacific is very large. It has been estimated that the temperature of the British Isles and Norway is raised several degrees by the warm poleward movement of waters in the North Atlantic. The temperature of the land is raised by this water, because the air over the warm ocean water is warmed and then blown over the land.

The milder climate of northwestern Europe, as compared with northeastern North America, is not due wholly to the northward movement of warm water. Even without such movement, the climate of northwestern Europe would be somewhat warmer in

winter than that of northeastern North America in the same latitudes, because the ocean, from which the winds of winter blow to northwestern Europe, still would be warmer than interior North America, whence the prevailing winds blow to the eastern coast of that continent.

There are some other less important causes of irregularities in the isotherms. Thus a basin region, shut in by mountains, gets hotter in summer than a region not so surrounded. Again, there is less evaporation from a dry surface than from a moist one, and since evaporation cools the surface, a dry surface will be warmer than a moist one, if other conditions are the same. The color of the soil, the presence or absence of vegetation, and other things, also affect the absorption and radiation of heat. The high temperature in the southwestern part of the United States in July (Fig. 26) is accounted for partly by the fact that the region is somewhat shut in by mountains, and has a dry, sandy soil but scantily covered with vegetation.

Altitude affects temperature, as already explained, but isothermal charts show no relation between isothermal lines and surface relief. The reason is that isothermal lines are represented on maps as if they were at sea-level. This is done by making allowance for altitude at the average rate of 1° F. for about 330 feet. Thus if the temperature of a place at an altitude of 3,300 feet is 60°, it is put down on the chart as 70° (60°+10°). Isothermal charts, therefore, are intended *to show the temperature as it would be if the land were at sea-level.*

Ranges of Temperature

Daily range. The temperature of a day when the sun shines is generally higher than the temperature of the night. The difference is as much as 40° or 50° F. in many places, and as much as 70° in some. The daily range of temperature of air over the ocean is much less than over the land; other things equal, less at high altitudes than at low altitudes, and less in moist regions than in dry ones.

The greatest importance of daily range of temperature is in connection with the growth of crops. Since many plants, including many food plants, are injured or killed by a freezing temperature (commonly called "frost"), they are restricted to regions where the temperature during the growing season does not fall as low as 32° F.

The danger of "frost" at night varies with local conditions, as (1) altitude, (2) exposure, (3) character of the soil, and (4) nearness to water bodies. Valley bottoms have frosts earlier in the autumn than neighboring hillsides, because the colder, heavier air moves down slopes and accumulates in low places. The great coffee plantations of São Paulo, Brazil, the olive and fig trees of Italy and Istria, the orange and peach orchards of California, and the vineyards in the Rhine Valley and in the south of France are found largely on hillsides.

Northern slopes are more subject to frosts than southern ones, because the latter are warmed more by day and hence must cool more at night before a freezing temperature is reached. Sandy soils are more liable to frost than clay soils situated similarly, for the reason that clay soils are usually wetter. The air above them contains more moisture, and so cools less readily. The condensation of moisture sets free heat and so checks further cooling. Of two crops on the same farm, one on clay soil, the other on sandy soil, the one may be untouched by "frost" on a night when the other is injured seriously. Places near water bodies, and in their lee (i. e., on the side toward which the wind blows from the water) have their temperatures influenced by the temperature of the water. Frosts at night in autumn are somewhat less common in such situations. The effect of large water bodies is seen in the location of important fruit districts on the lee (east) shore of Lake Michigan, and on the lee (southeast) shores of Lakes Erie and Ontario. A similar influence affects the important fruit and trucking industry of the peninsula between Delaware and Chesapeake bays. Frosts during the growing season are, in some cases, so destructive as to amount almost to national disasters. A frost in the late spring, after corn is well started, or in early autumn, before it is ripe, may reduce the crop of good corn by millions of bushels. When freezing temperatures extend into regions usually free from them, they do great damage to fruit, as to orange groves in Florida. A disastrous frost in December, 1894, affected this region.

The economic importance of frost is so great that the federal government has given much attention to methods for protecting perishable crops, and one of the most valuable services of the Weather Bureau is the sending out of frost warnings which give the farmers of the country anywhere from 6 to 24 hours to make preparation for protection. In this way, millions of dollars' worth of crops are saved every year. The cost of protection for several consecutive nights may not equal 1 per cent of the value of the crop saved.

The average daytime temperature during the growing season, and the number of days when the temperature is above a given point, are important matters, since most plants require, for growth, a temperature well above 32° F.

The daily range of temperature is also important to human beings, especially where the days are hot. Thus in desert regions the heat of midday may be much above 100° F.; but night temperatures in the same place may be as low as 45° or 50° F., making restful sleep possible.

It is the daily range of temperature which accounts partly for the invigorating effects of a vacation in the mountains.

Seasonal range. The seasonal range of temperature is affected by (1) latitude, (2) position with reference to land and sea, (3) prevailing winds, and (4) the presence of snow.

(1) The seasonal range of temperature increases with the latitude (compare Figs. 25 and 26), because the yearly variation of insolation increases with the latitude. San Diego and St. Paul (p. 47) are examples. In latitudes higher than that of St. Paul the range is still greater.

(2) Islands and coasts have a smaller range than continental interiors in the same latitude, because the range of sea temperature is less than the range of land temperature (Figs. 25 and 26). St. Louis and San Francisco (p. 47) are examples.

(3) A coast to which the prevailing winds blow from the ocean has a less range of temperature than a coast to which the prevailing winds blow from the land. Thus the range of temperature is less on the Pacific coast of the United States than on the Atlantic in the same latitude (Figs. 25 and 26), the winds being chiefly from the west in both cases.

(4) The presence of snow during the warm season, as in high latitudes and high mountains, prevents a high temperature, even though insolation is strong (p. 45). In the cold season, snow also tends to reduce the temperature of the lower air by reflecting a certain amount of insolation which might otherwise help to warm the land, and so the layers of air in contact with it. On the other hand, snow lessens the range of temperature of the soil beneath it, for snow checks radiation from the soil, and prevents it from being warmed by the direct rays of the sun. By preventing alternate freezing and thawing of the soil, snow is important to many plants, as, for example, winter wheat and clover.

Importance of temperature ranges. The annual range of temperature affects all industries connected with the soil. In general, the temperature of most importance to vegetation is the lowest or minimum temperature. For example, the palm-tree does not thrive where frosts occur; hence its natural distribution is limited to places where the lowest temperature of the year is above 32° F. Peach-trees, unless protected, are injured by temperatures below — 15° F. if they last long, and if such temperatures come often, peaches cannot be grown. For most crops, as corn, cotton, rice, tobacco, sugar cane, fruits, and vegetables, the length of time without freezing temperatures (the *growing season*) is a critical factor affecting their distribution.

Unseasonably low temperatures may destroy crops not only for that year, but in some cases for years to come. Thus, early in October, 1906, a temperature which was in places 13° below freezing killed hundreds of thousands of peach-trees in western Michigan. Peach-trees stand much lower temperatures in winter without injury, but this freezing temperature came before the trees were ready for it.

Questions

1. From what sources, besides the sun, does the earth's surface receive heat?

2. What temperature Centigrade corresponds to 45° F.? To — 45° F.?

3. Make a rule for changing degrees F. to degrees C., and vice versa.

4. The earth is probably not getting warmer, in spite of the fact that it is receiving heat all the time from the sun. Why?

5. On June 21st, in latitude 40° N., which would receive more heat, (1) a horizontal surface, or (2) a vertical surface of equal area facing south? On September 21st? Draw diagrams to illustrate answers.

6. For each of the various ways of heating a house, by (1) open fire, (2) stoves, (3) hot-air furnace, (4) steam, and (5) hot water, which process of heat distribution (radiation, convection, conduction) is most important?

7. In what way may satisfactory ventilation of a heated room be secured?

8. Why does snow mixed with dirt melt more rapidly than clean snow?

9. How does a lake tend to modify the temperature of the surrounding land by day? By night? In summer? In winter? Explain each.

10. Explain each important curve in the January isotherm of 10° F., northern hemisphere (Fig. 25).

11. (1) Compare and contrast the average January and July temperatures on the east and west coasts of the United States at the fortieth parallel (Figs. 25 and 26). (2) Explain the differences.

12. Why are the average annual temperatures over tropical lands higher than those over tropical seas?

13. Where do the highest July temperatures occur (Fig. 26)? Why there? The lowest January temperatures (Fig. 25)? Why?

14. Compare and contrast the seasonal range of temperature in the middle latitudes of the two hemispheres (Figs. 25 and 26). Why the difference?

15. Of two cities, St. Paul and Key West, one has an average daily range in temperature twice as great as the other. Which has the greater? Reasons?

16. Why is the average annual temperature higher in cities than in the surrounding country? Why is the daily range of temperature smaller in cities than in the country?

17. What is the length of the growing season in mountains, as compared with neighboring plains? Why?

CHAPTER VI

CLIMATIC FACTORS: MOISTURE

Importance of Atmospheric Moisture

We cannot see or smell or feel water vapor, though air with much water vapor has a different feeling from air with little.

The presence of vapor in the air may be proved in various ways. Drops of water often appear on the outside of a pitcher of ice-water in summer, and cold window panes often have "steam" on them in winter. In each case the water came from the air. Water vapor often condenses into water on the surface of dust particles in the air. Great numbers of these water-covered particles high in the air form clouds, from which rain may fall if the drops become heavy enough.

Water vapor is lighter than dry air; that is, a cubic foot of it weighs less than a cubic foot of dry air at the same temperature and under the same pressure. Water vapor in the air displaces some of the oxygen and nitrogen, and therefore makes the air lighter.

The moisture of the air is no less important than oxygen and carbon dioxide to animals and plants, for without it no life could exist on the land. It furnishes the rain and the snow which supply all springs and rivers, and it serves a most important function in connection with temperature, as already stated (p. 32). It increases the average temperature at the bottom of the atmosphere, and reduces the extremes of heat and cold which would exist if the air were altogether dry. This is shown by the fact that dry regions have greater ranges of temperature than moist ones in similar latitudes and altitudes. Moisture from the air also acts with the oxygen and with changes of temperature in the breaking up of rocks and the formation of soil from them (p. 162).

Evaporation

Sources of water vapor. Water left in an open dish disappears slowly, and muddy roads and wet pavements become dry after the rain ceases. The water *evaporates;* that is, it disappears in the form

of *vapor*. Vapor is passing from all moist surfaces into the air all the time. Evaporation also takes place from snow and ice, even at temperatures far below that of melting. Explorers in Arctic regions say that moist garments left on the snow during a clear night may be dry in the morning, even with a temperature of — 40° F. The moisture in the garments freezes, and the ice evaporates.

All animals breathe out water vapor into the air. This is seen on very cold days when the water vapor of the breath condenses, and so becomes visible. The water breathed out into warm air is not seen because it does not condense. Growing plants also give out moisture, the amount, in many cases, being very great.

A thrifty sunflower plant, during its life of 140 days, gave off 125 pounds of water. Grass was found to give off its own weight of water every 24 hours, in hot weather. This meant, where the measurement was made, 6½ tons per acre, or a little more than a ton for a lot 50 feet by 150 feet. A birch-tree, with some 200,000 leaves, was estimated to give off 700 to 900 pounds on a hot summer day, but much less on a cool day.

Water vapor also enters the air from all active volcanoes (p. 191). The oceans, however, are the great evaporating pans from which most water vapor comes, and but for them the waters of the land would all be dried up in the course of time.

Water is in constant circulation in the air. The circuit which it makes is somewhat as follows: (1) It is evaporated from the ocean (and all moist surfaces); (2) as vapor, it is diffused and blown over the land, where some of it (3) is condensed and falls as rain or snow. A part of the rain which falls on the land returns directly to the sea through rivers, a part sinks into the ground, and another part is evaporated again. About half the water vapor of the air is below an altitude of 6,500 feet. Its abundance near the bottom of the air is one reason why the lower air is warmer than that above (p. 44).

On the average, 30 to 40 inches of rain fall each year on land; that is, enough to make a layer 30 to 40 inches in average depth if spread out over all the land. The amount of water evaporated from the oceans each year is about the same as that which falls from the air. If *precipitation* (rainfall and snowfall) on the oceans is equal to that on the lands, square mile for square mile, and if all the water of the rain and snow came from the oceans and was not returned to them, the oceans would be dried up in 3,000 or 4,000 years. If an amount of water equal to all the rainfall of a year were evaporated from lakes, they would probably all be dried up in less than a year.

Rate of evaporation. The principal conditions affecting the rate of evaporation are (1) the amount of water vapor already in the air, (2) the temperature of the surface and the air over it, and (3) the strength of the wind. At a given temperature, *the less the water vapor in the air, the more rapid the evaporation from a water surface.* Raising the temperature of air from 30° to 50° F. doubles its capacity to hold water vapor, and hence increases the rate of evaporation. Air moving 10 miles an hour will evaporate four times as much water as still air, other things being equal.

Effect of evaporation on temperature. Evaporation cools the surface from which it takes place. If the hand be moistened, it feels cool as the water on it evaporates, and the faster the evaporation, the more distinct the cooling. Moist clothing seems cooler in wind than in still air, even when the temperature is the same, because wind increases evaporation. For the same reason, a day in summer when the wind is blowing seems cooler than a calm day when the temperature is the same.

Evaporation from forested regions in moist tropical lands is so great that the temperature there is much lower than would be expected from the insolation. The slight evaporation from dry regions is one reason why they are so hot in the sunny days of summer. Dry heat is less uncomfortable than damp heat because the increased evaporation from the human body in a dry region reduces its temperature. The hot, dry air of a furnace room causes far less discomfort than the less hot, damp air of a green-house. On the other hand, moist air at 0° F. *seems* much cooler than dry air at the same temperature.

Sensible temperature. The difference between temperature *as it seems* (*sensible temperature*) and temperature *as it is* (shown by the thermometer) is often great. Thus, observations in Death Valley, California, showed a maximum air temperature of 122° on five days, but the sensible temperatures ranged from 73° to 77° F. Yuma, Arizona, with an average temperature of 92° in July, does not seem so hot as Savannah, with a temperature of 82°, and but little hotter than Boston, with a temperature of 72°. This is because the air at Yuma is very much drier than that at Savannah or Boston. Sensible temperatures bear a very important relation to sunstroke and heat prostration, both of which are almost unknown in our dry southwestern states, but are of frequent occurrence along the less hot but more moist eastern coast.

Saturation. The amount of water vapor in the air varies greatly from place to place, and from time to time at the same place. When

there is as much water vapor in the air as there can be under existing conditions, it is said to be *saturated*. A cubic foot of air at 0° F. is capable of containing ½ grain of water vapor; at 30°, about 2 grains; at 60°, 5 grains; at 80°, 11 grains; and at 90°, nearly 15 grains. Thus the higher the temperature the greater the amount of water vapor necessary for saturation.

HUMIDITY

Absolute and relative humidity. The amount of moisture which the air contains is its *absolute humidity*. The percentage of moisture which air contains at any temperature, compared with what it might contain at that temperature, is its *relative humidity*. If a cubic foot of air at 30° F. contains 2 grains of water vapor, it is saturated, and its relative humidity is 100 per cent. If the temperature is raised to 60° F., its capacity for water vapor is increased from 2 grains to 5 grains, and its relative humidity is then 40 per cent. On the other hand, if air at 80° F., containing 5 grains of water vapor (relative humidity about 46 per cent), were cooled to 60° F., the 5 grains would mean saturation for that temperature. Air is said to be "dry" when its relative humidity is low, and "moist" when its relative humidity is high. Thus 5 grains of water vapor in air at 90° F. means dry air (humidity 33), while the same quantity of water vapor in air at 60° F. means damp air. The air over damp England and that over the dry Sahara, for example, may have the same actual amount of water vapor per cubic foot.

The average relative humidities in the United States range from 80 along the coasts to less than 40 in some parts of the southwest. Areas where the relative humidity is 35 or less are essentially desert, and areas where it is less than 50 are distinctly dry. The average relative humidity of air over the land is probably about 60; that over the ocean about 85. In that part of the United States where ordinary farming can be carried on without irrigation, the relative humidity is, as a rule, more than 65.

Importance of relative humidity. Corn, wheat, and rye, require, respectively, about 14, 10, and 8 inches of water during their growing seasons. If the total rainfall of a given place is 18 inches in that time, any one of the crops would seem to have enough. But if the relative humidity is very low, evaporation is rapid. In this case 18 inches of rain may be necessary to grow rye.

Relative humidity has important effects on the human body. Moisture is all the time being evaporated from the skin and lungs. High humidity checks evaporation, and this seems to be one cause of certain diseases in moist tropical

regions. Low humidity increases evaporation from the body, and this is, on the whole, stimulating. Sudden changes from low to high humidity, especially when associated with sudden changes of temperature, such as occur when one goes out from a warm house in winter, probably favor diseases of the breathing organs (cold, etc.), so frequent at that season.

High relative humidity hastens the decay of food, especially meat; hence many foods cannot be kept long in warm, moist places. This is perhaps one reason why little meat is used in tropical countries. Unprotected iron wares rust rapidly in damp air. The damp air of the coast of Maine prevented the successful development of the sardine industry, in spite of a law providing that the drying should be done only on "dry clear days," until a special method of curing the fish made it possible to compete with the French product dried out of doors. In some places meat is dried in the air, giving the so-called "jerked beef." Even "burial" of the dead may be on high platforms in regions where dry air quickly mummifies the body.

Extreme dryness and the evaporation which goes with it cause wood to shrink, warp, and crack to such an extent that boxes which were strong fall apart. Goods to be shipped far through a very dry region need special preparation, and even railroad cars have to be of steel to withstand the effect of desert dryness. Humidity is so important in textile industries, as in spinning cotton, that the early centers of cotton manufacture tended to develop in damp regions. In many mills, special devices are now used to maintain uniform humidity.

Dew point. If saturated air (p. 59) is cooled, some of its water vapor is *condensed* (becomes liquid). The temperature at which it begins to condense is the *dew point*. Air may be brought to the dew point in various ways: (1) It may be blown where the temperature is lower, as to a higher latitude or altitude; (2) it may be cooled by having cooler air brought to it, as by a cold wind; (3) it may be cooled by radiation, or (4) by expansion, as when it rises.

The temperature of the dew point is not fixed, but is influenced by the amount of water vapor in the air, as already explained (p. 59). If air at 80° F. contains 5 grains of vapor per cubic foot, its dew point will be reached when it is cooled to 60° F.; but if the amount of water vapor in air at 80° F. is only 2 grains per cubic foot, the dew point would not be reached until it had been cooled to 30° F.

If the temperature of condensation is above 32°, the vapor condenses into liquid water, which at first takes the form of droplets, such as those of which fog is made. If the temperature of condensation is below 32°, particles of ice form as the vapor condenses. They may be the beginnings of snowflakes, or they may be particles of frost. The condensation of water vapor sets free an amount of heat equal to that absorbed in its evaporation. This heat checks the cooling, a fact of importance where the temperature of condensa-

tion is near 32° F., and where continued cooling would bring the temperature to the freezing point.

Dew and frost. In the clear, still nights of summer and autumn, the temperature of the surface of the land, cooling by radiation, often becomes lower than the dew point of the air above. Moisture then condenses on the surface. Such moisture is *dew* if the temperature of condensation is above 32°. The water which condenses on

Fig. 27. Fog over the lowlands, as seen from Mount Wilson, California. (Ellerman.)

the outside of a pitcher of ice water (p. 56) is dew, just as much as that which forms on grass blades. Dew does not fall, but *condenses* on the surface of solid objects. When the temperature of the dew point is below 32° F., the moisture which condenses on solid objects condenses as ice particles, or *frost*, instead of dew.

Dew is more likely to form on still nights than on windy ones, because wind tends to move away air which is approaching its dew point, supplying other air in its place, and the incoming air may be warmer or drier than that which moved on. Dew is more likely to form on clear nights than on cloudy ones, because radiation and cooling are greater when there are no clouds. This association of dew with clear skies led the ancients to believe that dew came from the stars.

Fog and cloud. The condensing of water vapor in the air into droplets makes *fog* (Fig. 27) if the droplets are in the lower part of

the atmosphere at a temperature above 32° F. It makes ice particles, or frost, if the temperature is below 32° F. Water droplets and ice particles in large numbers make *clouds* if formed well above the bottom of the atmosphere (Figs. 28–31). Fog may be said to be cloud resting on the surface of land or water. The droplets of water forming fog and cloud are very small, many of them not more than 1/3000 of an inch in diameter.

Fogs are formed in many cases where the moist air over warmer water (e.g., a warm ocean current) blows over a colder surface of water or land. They often form in valleys at night (Fig. 27), especially in autumn, when the night temperatures are much lower than those of the day. The cooler air settles in the valleys, and the air there is more likely to be brought to the dew point than that over the uplands. Fogs occur more frequently in large cities than in the nearby country, apparently because the large numbers of solid particles poured into the air in the form of smoke favor condensation. In London, fogs increased as more coal was burned until the "smoke nuisance" was partly stopped; then the fogs decreased. In other places, also, doing away with smoke has nearly put an end to fogs.

Fogs interfere with all kinds of traffic. They are the most common cause of disasters at sea, as in the collision of the French steamship La Burgogne with an iceberg in the North Atlantic, as a result of which more than 600 lives were lost. Coastwise traffic, as in Nantucket Sound, or traffic in river harbors, as at Philadelphia, is kept at a standstill for days at a time by fogs. Fogs also have caused many railway accidents.

In some places where fogs are frequent and heavy, they may serve as a source of moisture. The distribution of the redwood tree in California corresponds closely to the zone over which fogs extend inland. Along some African rivers the moisture from valley fogs, always drifted one way by the winds, causes heavier vegetation on one bank than on the other. Attempts by men to utilize the moisture of fogs have never proved very successful.

Forms of clouds. Clouds take many forms. (1) *Cumulus clouds* are thick, with upper surfaces somewhat dome-shaped, and with irregular and fleecy projections. Their bases are nearly horizontal (Fig. 28). They are formed from the water vapor in ascending convection currents, and their level bottoms seem to mark the altitude at which condensation takes place as the air rises. Their bottoms are usually somewhere from 1,800 to 4,000 feet above the land, but the tops may rise three or four miles higher. They appear, especially in clear, hot weather, in mid- or late-forenoon, after insolation has established convection currents. They attain their greatest size at about the hour of maximum heat. As evening approaches they commonly grow smaller and disappear. (2) *Stratus clouds* are horizontal sheets of cloud, often not more than 1,000 feet above the earth. (3) *Nimbus* or *rain clouds* (Fig. 29) consist of thick masses of dark

clouds without definite shape and with ragged edges, from which continued rain or snow generally falls. Nimbus clouds are rarely more than half a mile above the earth's surface. (4) *Cirrus clouds* are delicate, fibrous, or feathery (Fig. 30). They are generally white,

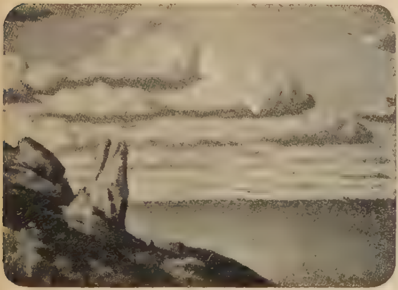


Fig. 28.

Fig. 29.

Fig. 30.

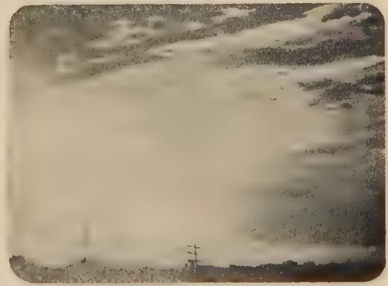


Fig. 31.

Fig. 28. Cumulus clouds. (Cloud chart, Hydrographic Office, Dept. of Navy.)

Fig. 29. Cumulo-nimbus clouds. (Cloud Chart, Hydrographic Office, Dept. of Navy.)

Fig. 30. Cirrus clouds. (Cloud Chart, Hydrographic Office, Dept. of Navy.)

Fig. 31. Cirro-stratus clouds. (Cloud Chart, Hydrographic Office, Dept. of Navy.)

and sometimes arranged in belts. They are usually high, five miles or more, and thin, and probably always consist of particles of snow or ice. Between these types of clouds there are many gradations, of which perhaps the most interesting is the *cirro-stratus* (Fig. 31), a thin, veil-like cloud, almost imperceptible, usually extending in a sheet over a large part of the sky.

In general, cirrus and cumulus clouds are fair-weather clouds, and do not give precipitation. The latter, however, may grow into the cumulo-nimbus or summer thunder cloud (Fig. 29), lose their fleecy whiteness, and produce rain. Cirro-stratus, stratus, and nimbus clouds are more likely to be foul-weather clouds.

Cloudiness and sunshine. The chief importance of clouds is found in their relation to (1) precipitation and (2) sunshine. Clouds cut off sunshine and reduce the amount of insolation; hence they lower day-time temperatures. Clouds also check radiation, and so tend to keep night temperatures higher. Cloudy regions, therefore, have less variable temperatures than clear ones. Through their effect on temperatures, clouds also affect humidity and evaporation, raising humidity and lowering evaporation. Hence cloudy places are generally cool and damp and the types of vegetation and the crops grown there are different from those of places in the same latitude where clouds are few. Thus there are few vineyards in cloudy regions, wine production being typical of sunny countries.

In general, great cloudiness goes with great relative humidity. Cloudiness is somewhat greater in winter than in summer, greater in higher latitudes than in low ones, and greater along sea-coasts than in continental interiors. The sunniest parts of the earth are hot deserts.

Precipitation. The condensation of the water vapor of the air leads to rain, snow, or hail, if the products of condensation fall. Whether precipitation really takes place after the formation of clouds, depends on many conditions. To give rain or snow, the particles of water or snow in the cloud must be large enough to fall. Drops of rain vary in diameter from $^1/_{50}$ to $^1/_5$ of an inch. If they are to reach the ground they must not pass through air which is dry enough and warm enough to evaporate them before they reach the bottom of the atmosphere. In desert regions, water may sometimes be seen to be falling from a high cloud, when not a drop reaches the ground. The falling drops evaporate as they descend.

Precipitation and evaporation. The *distribution of rainfall* depends, in large measure, on the winds, and will be considered later. The amount of rain necessary for crops is affected greatly by relative humidity and evaporation. Thus two localities which have the same amount and seasonal distribution of rainfall may have very different sorts of plants, because more of the precipitation in one place is evaporated quickly.

In some parts of western Texas, with a precipitation of 22 inches, there is too little moisture for crops unless they are grown by "*dry-farming*" (p. 329), and the region is given over largely to grazing. In the valley of the Red River in Minnesota and North Dakota the precipitation is a little less; yet this is one of the most important wheat regions of the world. The difference between the two regions is due chiefly to the fact that evaporation is about 2½ times as great in Texas as in the Red River Valley, because of the higher temperature in the former place.

In many other localities where rainfall is scanty, evaporation is one of the most important of all climatic factors, so far as vegetation is concerned. Dry-farming depends partly on the principle that if evaporation from the soil is checked, even scanty rainfall (15 inches yearly) may suffice for hardy crops like wheat. The so-called "hot winds" which sometimes do great damage to the corn crop, as in Kansas and Nebraska, owe their destructiveness chiefly to the rapid evaporation caused by their warmth and dryness. If these winds were moist, their temperature would not hurt the corn. Desert plants have peculiar characteristics such as fleshy leaves and smooth, shining surfaces, developed apparently with reference to preventing loss of moisture by evaporation.

Questions

1. Why is the crop in a grain field poor around the base of a tree?
2. Where, in middle latitudes, would you expect the sensible temperature to be highest in summer? In winter? The same for tropical regions.
3. Why is the relative humidity in houses in winter different from that out of doors, even where the furnace has a supply pipe taking in outside air?
4. What is the effect of the indoor relative humidity in winter on the amount of fuel burned?
5. Beds of rock salt are found underground in some places. What conclusion may be drawn as to the climate when the deposit was formed?
6. Why does fog in the evening appear first close to the ground?
7. Why are clouds rarely formed above an altitude of 10 miles?
8. Why does most of the heavy precipitation come from low clouds?
9. What is the reason for the formation of more dew on surfaces of stone or metal than on pieces of wood near by?
10. Explain the fact that the lower leaves or branches of a plant may be nipped by frost, when the upper parts of the same plant are unaffected.
11. Why is frost less likely to occur on cloudy than on clear nights?
12. Why are frosts less common after heavy rain than at other times?
13. Why does a covering of newspapers or of thin cloth often protect plants from frost?
14. Suggest other means by which protection from frost might be secured for large fruit orchards and truck farms.
15. At what time of day is relative humidity lowest, on the average? Why?

CHAPTER VII

CLIMATIC FACTORS: PRESSURE AND WIND

Pressure

Importance of pressure. The downward pressure (or weight) of the air is about 15 pounds to the square inch at sea-level. The pressure varies a little from time to time at any given place, and is rarely the same at any two places more than a few miles apart. In themselves, variations of pressure have little effect on life; but the variations have much to do with winds and other elements of weather, and weather is most important to life. Hence it is desirable to have some simple method of measuring and recording atmospheric pressures. The instrument by which they are measured is the *barometer*.

Fig. 32. Diagram to illustrate the principle of the barometer. The pressure of the air at *A* maintains the mercury at *B* in the tube when there is no air in the tube above *B*.

The barometer. The principle of the barometer is as follows: A tube more than 30 inches long, closed at one end, is filled with mercury. The open end of the tube is then placed in a dish of mercury (Fig. 32). The mercury in the tube will sink until its upper surface reaches a level about 30 inches above the level of the mercury in the dish, if the place of the experiment is at sea-level. The mercury remains at this height in the tube, because the pressure of the air on the mercury in the dish is enough to balance the weight of the mercury in the tube. Since the normal pressure of the air at sea-level balances a column of mercury about 30 inches high, the pressure of the air at sea-level is said to be 30 inches. If the pressure is more than 30 inches it is said to be *high;* if less than 30 inches, *low.* At sea-level the variation above and below 30 inches is rarely more than one inch.

Pressure and altitude. At elevations above sea-level the pressure grows less. Thus the normal pressure is about 28 inches 1,800 feet above sea-level, about 24 inches at 6,000 feet, and about 20 inches at 10,500 feet.

The rate of decrease of pressure with increasing height being known, the altitude of a place above sea-level may be measured by means of the barometer. A special form of barometer has been devised for this purpose.

The decrease of pressure with altitude explains some of the discomforts, such as mountain sickness, experienced by many mountain climbers. After a short stay at relatively high altitudes, these discomforts disappear in most cases.

Distribution of pressure. The pressure of the atmosphere at sea-level varies from point to point, and from time to time at the same point. Some of the reasons are: (1) The temperature of the surface on which the air rests is unequal, and increase of temperature makes the air lighter. As the temperature varies, the pressure varies. (2) Water vapor in the air makes the air lighter (p. 56). The amount of moisture in the air is greater in warm regions (but not in hot deserts) than in cold ones, and greater over moist surfaces than over dry ones. Since the amount of moisture in the air varies from time to time, the pressure is changing constantly.

Representation of Pressure on Maps and Charts

Isobars. For convenience in the study of pressure distribution, lines may be drawn on maps connecting points where the atmospheric pressure is the same. Such equal-pressure lines are *isobars*. A map showing lines of equal pressure is known as an *isobaric map* or *chart*. An isobaric chart for the year shows isobars connecting points having the same *average pressure* throughout the year. There may be isobaric charts for a season, for a month, or for shorter periods. The daily weather maps are daily isobaric charts. Fig. 33 is an isobaric chart for the year. The figures on the lines indicate the average pressure for the year in inches.

In the southern hemisphere, the isobar of 30 inches encloses a belt extending almost around the earth, being interrupted only near Australia. Every point within the area enclosed by this isobar has an average atmospheric pressure of more than 30 inches. Every point within the isobar of 30.10 inches has an average annual pressure of more than 30.10 inches, while every point between the isobars of 30 and 30.10 has an average annual pressure of more than 30 and less than 30.10 inches, etc. Between the two adjacent isobars of 29.90 in the equatorial part of the Atlantic, the pressure is, on the average, less than 29.90, but not so low as 29.80. If the

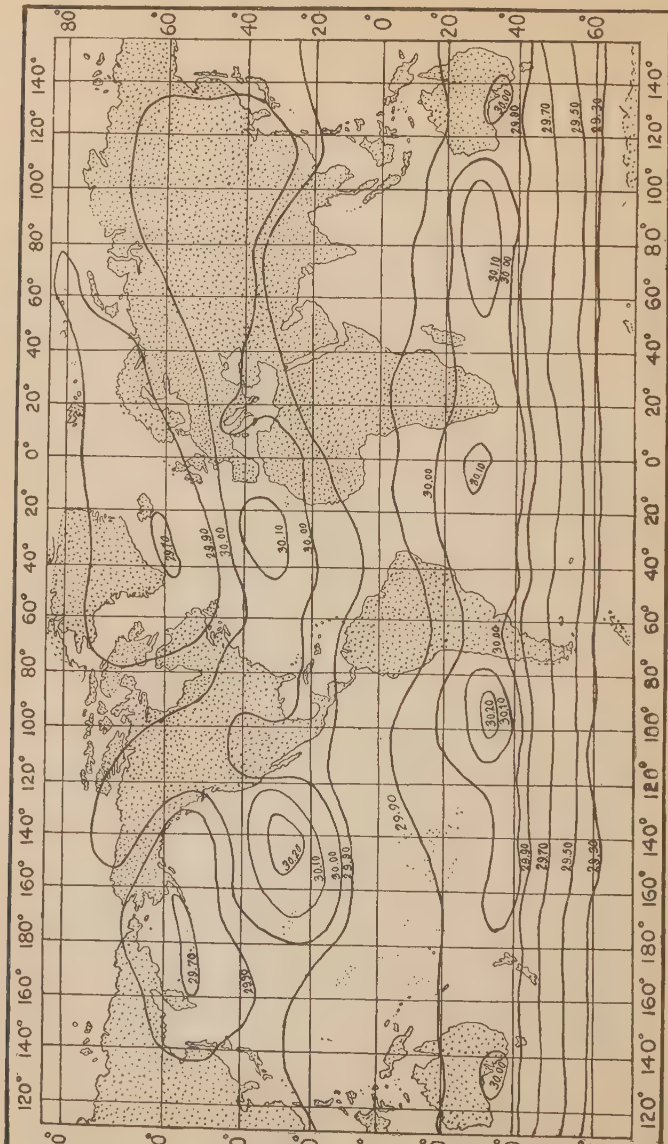


Fig. 33. Chart of mean annual isobars. (After Buchan.)

pressure sank to the latter figure, there would have been an isobar of 29.80 inches.

It will be remembered that in the case of the isothermal chart allowance is made for altitude above sea-level. In the same way, the pressures shown on land on an isobaric chart are those which would exist if there were no elevations above sea-level. For low altitudes the pressure decreases about .1 inch for each 90 feet of rise.

Courses of isobars. Returning to Fig. 33, several points are seen readily: (1) The isobars have a general east-west course, though many of them are not straight; (2) on the average, they show greater pressure in low latitudes than in high latitudes; (3) they are highest (that is, they show highest pressures) in the latitudes just outside the tropics; (4) they are more regular in the southern hemisphere than in the northern; and (5) they are, on the whole, more regular on the sea than on the land.

The isobaric map for January (Fig. 34) shows also that a high-pressure belt is very wide in the northern hemisphere, especially on the land, which at this season (winter) is cooler than the sea. This fact suggests that high pressure goes with low temperature. In the southern hemisphere, January is a summer month, and the land is warmer than the sea. If high temperature causes low pressure, the pressure in the southern hemisphere at this time should be less than that in the northern, and it should be lower on the land than on the sea. The map shows that both these things are true. This chart, therefore, seems to show that high temperature reduces pressure.

A study of the isobaric chart for July (Fig. 35) leads to the same conclusion. At that time of year, the pressure in the southern hemisphere (winter) should be higher, on the average, than in January (Fig. 34); especially should it be higher on land, as the map shows it to be. In the northern hemisphere in July, on the other hand, the pressure should be less than it was in January, and especially should it be less on land, which is much warmer than it was in winter. Fig. 35 shows both these things to be true. We have confidence, therefore, in the conclusion that high temperature reduces the pressure, while low temperature increases it. The charts furnish other evidences in support of the same conclusions.

If temperature alone controlled pressures, they should be lowest near the equator, where it is warmest, and highest near the poles, where it is coldest. Fig. 33 shows that the average annual pressures are distributed in apparent disregard of temperature, for the pressures

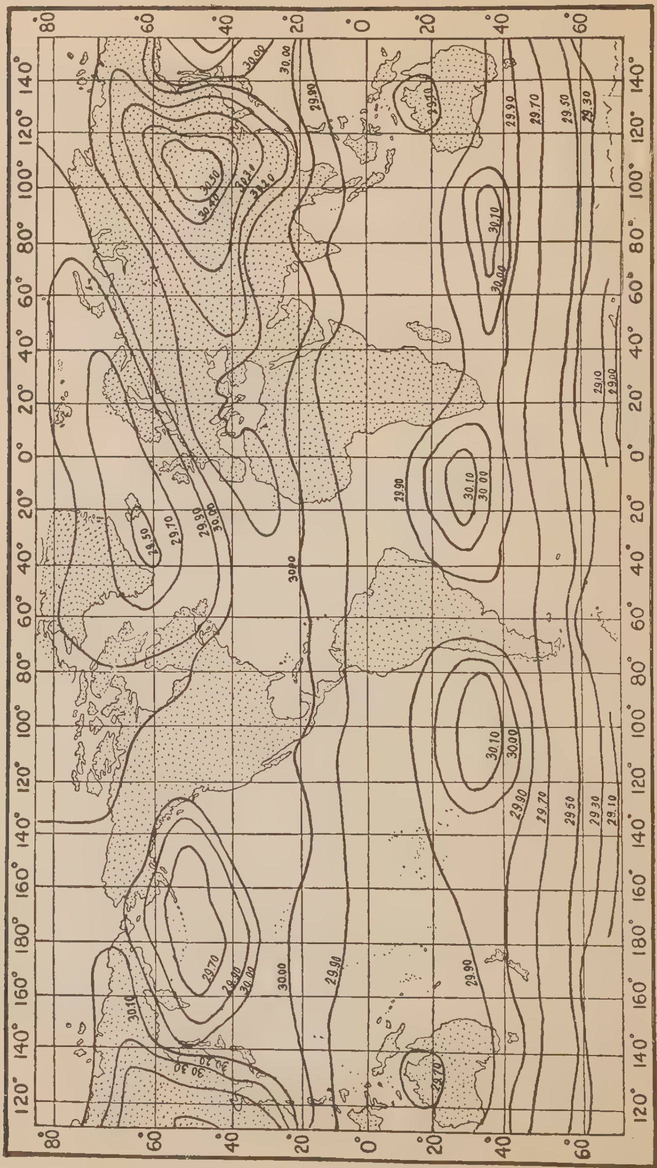


Fig. 34. Chart of isobaric lines for January. (After Buchan.)

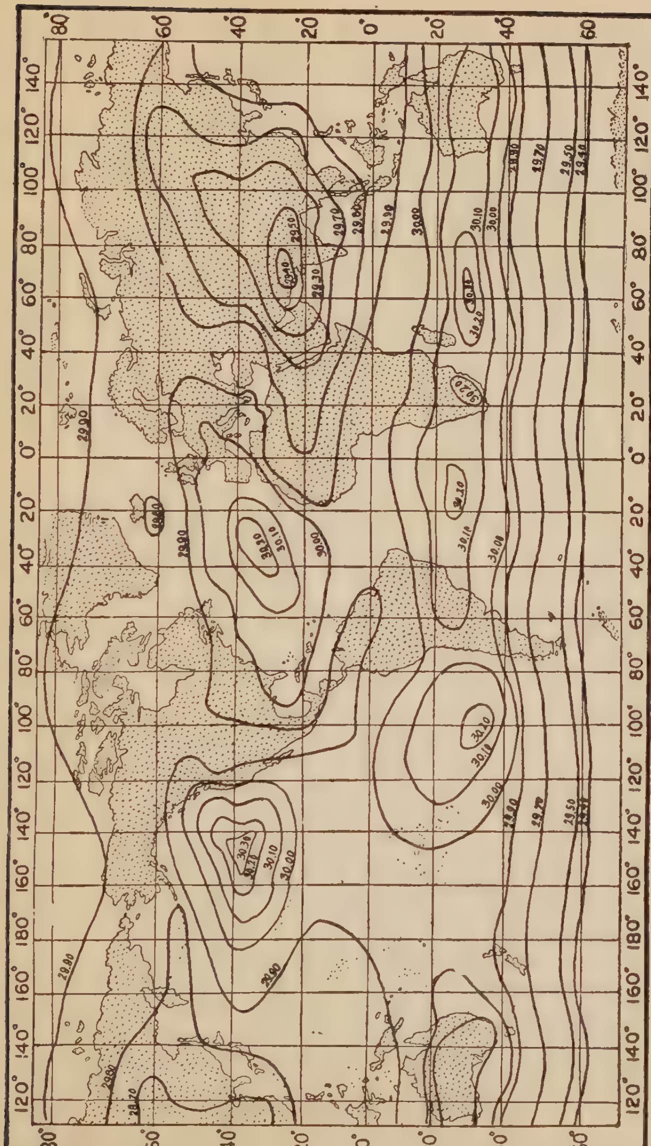


Fig. 35. Chart of isobaric lines for July. (After Buchan.)

are highest neither where it is coldest nor where it is warmest. It is clear, therefore, that neither temperature nor latitude entirely controls the distribution of pressure.

Isobars and humidity. We have seen (p. 56) that water vapor makes the air lighter. But the isobars are not lowest over the oceans in warm latitudes, where the air contains, on the average, most moisture. We conclude, therefore, that the amount of moisture in the air is not the chief factor controlling the isobars.

Inequalities of temperature and moisture in the air are the only factors thus far studied which might affect the isobars; and since they do not explain the most striking feature in the distribution of atmospheric pressure, namely, the high pressures in relatively low latitudes, we conclude that something besides temperature and moisture must be involved in their explanation. The explanation of the high pressures just outside the tropics is not found on the isobaric charts, and will not be discussed here.

Winds

Importance. Horizontal movements of air are *winds*. Winds are important in many ways, as in carrying away the impurities of city air, in transporting dust and sand (p. 201), in furnishing power for windmills and sailing vessels, in increasing evaporation (p. 58), and in distributing the moisture of the air (p. 76). Winds also affect human beings directly, for they lower the sensible temperature, and are, as a rule, invigorating, while calm air (if warm) is enervating.

Winds are produced by unequal pressures at the same level. These inequalities are being renewed all the time by unequal heating, and in other ways; hence winds always are blowing.

Relation of winds to the distribution of insolation. If the air over the whole earth were quiet at a uniform low temperature, and if it could then be heated by the sun for a time without any horizontal movement, the effect would be to raise its surface everywhere, and to raise it most where it was heated most, that is, in low latitudes (Fig. 36). Under these conditions there would be a *barometric slope* from low latitudes toward high latitudes. *Before horizontal movement began*, there would be no change of pressure at the bottom of the air, for the same amount (mass) of air would lie over each place, as before the heating. But if the surface of the air had the form shown by the dotted line in Fig. 36, the upper

air would move as shown by the arrows. Since the air in low latitudes is always warmer than that in high latitudes, the upper air should always be moving from the equatorial zone toward the polar zones in both hemispheres. These poleward movements of the upper air lessen the pressure at the bottom of the atmosphere in low latitudes, because air has moved away from them. *After air has moved from the equatorial region toward the poles* (Fig. 36), there is more air over a given spot in high latitudes than in low. A barometric slope is thus established *toward the equator at the bottom of the atmosphere.* Air then moves from higher latitudes to lower latitudes at the bottom of the air (Fig. 37). Here, then, we have the

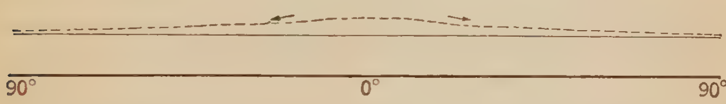


Fig. 36. The lower line may be taken to represent the surface of the earth; the upper solid line, the outer surface of the atmosphere as it would be if the temperature were everywhere equal. The dotted line shows the effect of heating on the surface of the air. Movement would result as indicated by the arrows.

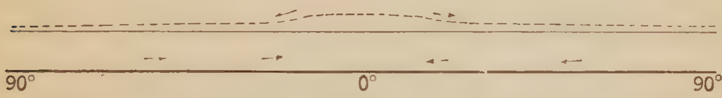


Fig. 37. The movement of air indicated in Fig. 36 would result in further movement as shown by the lower arrows in this figure.

elements of a general circulation, a poleward movement in the upper air, and an equatorward movement in the lower air. The unequal heating which generates these movements is in operation all the time.

Effect of the extra-tropical belts of high pressure. From the belts of high pressure just outside the tropics the air flows to areas of lower pressure on either side, at the bottom of the atmosphere, giving rise to distinct wind zones. If the earth did not rotate, these movements of air would tend to follow meridians. Rotation, however, turns the air currents to the right in the northern hemisphere, and to the left in the southern. It follows that the winds blowing poleward from the high-pressure belts are turned toward the east in both hemispheres, and so become *westerly winds* (southwesterly in the northern hemisphere, and northwesterly in the southern;

Fig. 38). The winds blowing from the belts of high pressure toward the equator become *easterly winds* (northeasterly in the northern hemisphere, and southeasterly in the southern), and are known as *trade-winds* (Fig. 38). The zone along the equator, where the northeasterly and southeasterly trades meet, and where rising currents of air are stronger than horizontal movements, is known as the *zone of equatorial calms*, or "*doldrums*." The position of this zone of calms shifts a little with the sun.

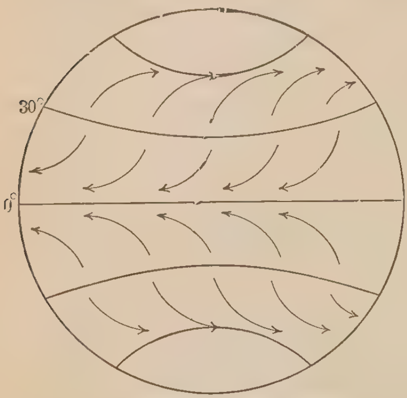


Fig. 38. Generalized diagram of wind directions at the bottom of the atmosphere.

The westerly winds of middle latitudes and the trades of low latitudes are the *prevailing winds* (*planetary winds*) at the bottom of the atmosphere.

Periodic Winds

When air is heated it expands, and a given volume of it becomes lighter. This results in movements of convection (Fig. 37). One of the movements involved in convection is horizontal, and horizontal movement of the air is wind. On a cold day in winter, with a brisk open fire, cold air may be felt moving along the floor toward the fire. Such movement is analogous to wind. *Unequal heating of the air is, therefore, a cause of air movements*, and since the air is being unequally heated all the time, unequal heating is a cause of constant atmospheric movements. Some of the movements are horizontal, and some vertical; some are in the lower part of the air, and some in the upper.

The unequal heating of the air is the immediate cause of certain familiar winds and breezes which blow at more or less regular periods and also interfere with the circulation indicated in Fig. 38.

Land- and sea-breezes. On a sunny summer day, the land becomes warmer than a nearby lake or sea (p. 40). The result is that the air over the land is warmed and expanded more than that over the sea, and air moves in from the water to the land, at the bottom of the atmosphere. This is the *sea-breeze* or *lake-breeze*. At night the land cools more than the water, and the air blows from the land to

the water, giving the *land-breeze.* The sea-breeze is strongest during the summer, and in warm regions. In many places it is felt inland 20 to 30 miles. It lowers the temperature over the land to which it blows, and makes the conditions of life on many tropical coasts much more agreeable than they would be otherwise. It is partly because of the cool, refreshing sea-breeze that many people go to the sea-shore during the hot months. The effects of the sea-breeze are so beneficial in many places in the tropics that the natives of those regions call the sea-breeze the "doctor." Along certain coasts, fishermen put to sea in the early morning with the land-breeze, and return toward night with the sea-breeze.

Monsoons. Some lands near the sea become so warm in summer that sea (from-sea) winds blow throughout the hot season, while land (from-land) winds hold sway during the winter. This is the case in India. Such winds, which change their directions with the seasons, are *monsoon winds.*

Monsoon winds influenced greatly the development and conduct of trade on the Indian Ocean, sailing vessels timing their voyages so as to take advantage of them. The monsoon winds of India have much to do with bringing moisture from the ocean, thus influencing the rainfall upon which the crops to feed 250,000,000 people depend.

Monsoon winds, or winds very much like them, are not confined to India. Winds blow from sea to land in summer and from land to sea in winter on the east coast of Asia. Spain affords another excellent example of seasonal winds.

Besides the winds mentioned above, whose times of blowing are more or less regular, there are winds which blow at irregular times, and whose coming cannot be foretold long in advance. These irregular winds are the chief cause of the uncertain elements of the weather. They will be considered in the next chapter.

Wind velocities. Wind velocities are expressed usually in miles per hour; thus the trade-winds are said to blow from 10 to 30 miles an hour. The United States Weather Bureau also uses descriptive terms (as light, fresh, brisk) for a regular scale of wind velocities. A wind velocity of 60 miles per hour causes a wind pressure of nearly 10 pounds per square foot at sea-level, while at 90 miles an hour this pressure is doubled. Hence the destructive violence of winds of high velocity. The greatest velocities, rising to 100 or more miles per hour, always are associated with irregular winds.

The average velocity of winds is greater over the sea than over the land, because moving air is checked on land by friction with the uneven surface. It is greater in the upper air than in the lower, for the same reason. But the *force* of the wind at high altitudes is less than for the same velocities at sea-level, owing to the less density of the air above.

Winds and Rainfall

Importance of rainfall. Perhaps the greatest service of the wind is in carrying moisture from the places where it is evaporated to the places where it is precipitated. Rainfall is of great importance to all plants and animals which live on the land. Human activities, too, are much affected by rainfall, for no arid region supports a dense population, and no agricultural country, aside from small irrigated areas, can be prosperous if the rainfall is unreliable.

Less than one-thirtieth of the people of the United States live in the third of the country where the rainfall is less than 20 inches per year. Soil is not productive unless adequately watered, even though it be rich in the elements necessary for plant food.

Twenty inches of rain per year usually is considered to be the minimum for general agricultural purposes, but something depends on (1) temperature, (2) the soil, and very much on (3) the time of year when the rain falls and (4) the rate of evaporation, as determined by temperature, soil, and wind (pp. 59, 65). The warmer and drier the climate, the more the water needed for crops. A very porous soil loses its moisture more quickly than a more compact one, and so needs more rain for crops. The total amount of rain necessary for agriculture is less if it falls when the growing crops need it most.

Rain and snow are important not only as a source of water for soil, but as a source of supply for streams and wells. A mantle of snow also prevents great changes in the temperature of the soil beneath, and in this way protects many plants. So important is this effect that in some regions a heavy snow generally means good yields of fall-sown crops the next year. Snow hampers some kinds of transportation and favors others. In lumbering, for example, snow makes the hauling of logs easier. Rapidly melting snow and heavy rainfall on frozen ground cause destructive floods. Heavy rain in a city is beneficial in flushing and cleaning the streets and in washing impurities out of the air. On the other hand, it may flood cellars and basements, doing great damage. Both rain and snow hinder the circulation of dust and bacteria, thus further contributing to health.

The precipitation of any given region depends largely on (1) what winds affect it, (2) the topography of the surface over which the winds blow before reaching it, and (3) the topographic situation and relations of the place itself.

Rainfall in the zones of the trade-winds. In the trade-wind zones, the winds blow from higher to lower latitudes, and therefore, on the average, from cooler to warmer places. As the air is warmed, it can hold more moisture. So long as the trades blow over the sea or low land, they take moisture, but do not drop what they have. It follows that on the sea, and on comparatively low lands, like the Sahara and parts of Australia, the trade-winds are "dry." If, however, the air of the trades is forced up over mountains, it is cooled, and some of its moisture may be precipitated. *The windward sides of high mountains in the trade-wind zone have heavy rainfall.* An illustration is afforded by the east side of the Andes Mountains in the trade-wind zone (Fig. 39). Even in the midst of the Sahara and of Australia, some rainfall is caused by high hills and mountains which stand in the path of the trade-winds.

After the air of the trades passes over a mountain range, it descends and is warmed both by contact with the warm surface and by compression. It accordingly takes up moisture. *The leeward sides of mountains in the trade-wind zones are therefore regions of little precipitation.* The west slope of the Andes Mountains in the zone of the trades furnishes an example in the coastal desert of Peru.

Rainfall in the zones of the prevailing westerlies. The westerly winds are, on the whole, blowing from lower to higher latitudes, and so are being cooled gradually. They may, therefore, yield some moisture even at sea-level or on low land, and especially on land in the winter season. The heat of the land in summer often prevents condensation and precipitation of the moisture in the westerly winds until the air has moved far to poleward. But when such winds cross mountains, they yield moisture to the windward slopes and summits, and become dry on the leeward slopes (Fig. 39).

From these principles we may understand the rainfall of the United States, so far as it depends on planetary winds. The prevailing winds for most of the country are from the southwest. Coming to the land from the Pacific Ocean, these winds find the land cooler than the ocean in winter, and warmer in summer. In winter they yield moisture, even at low levels. This gives the low lands of California their wet season. As the winds blow across the mountains back from the coast, they yield more moisture, so that all the area west of the top of the first high ranges, the Sierras at the south and the Cascades at the north, is supplied with rain and snow in the winter season. As the winds blow beyond the Sierra Nevada and

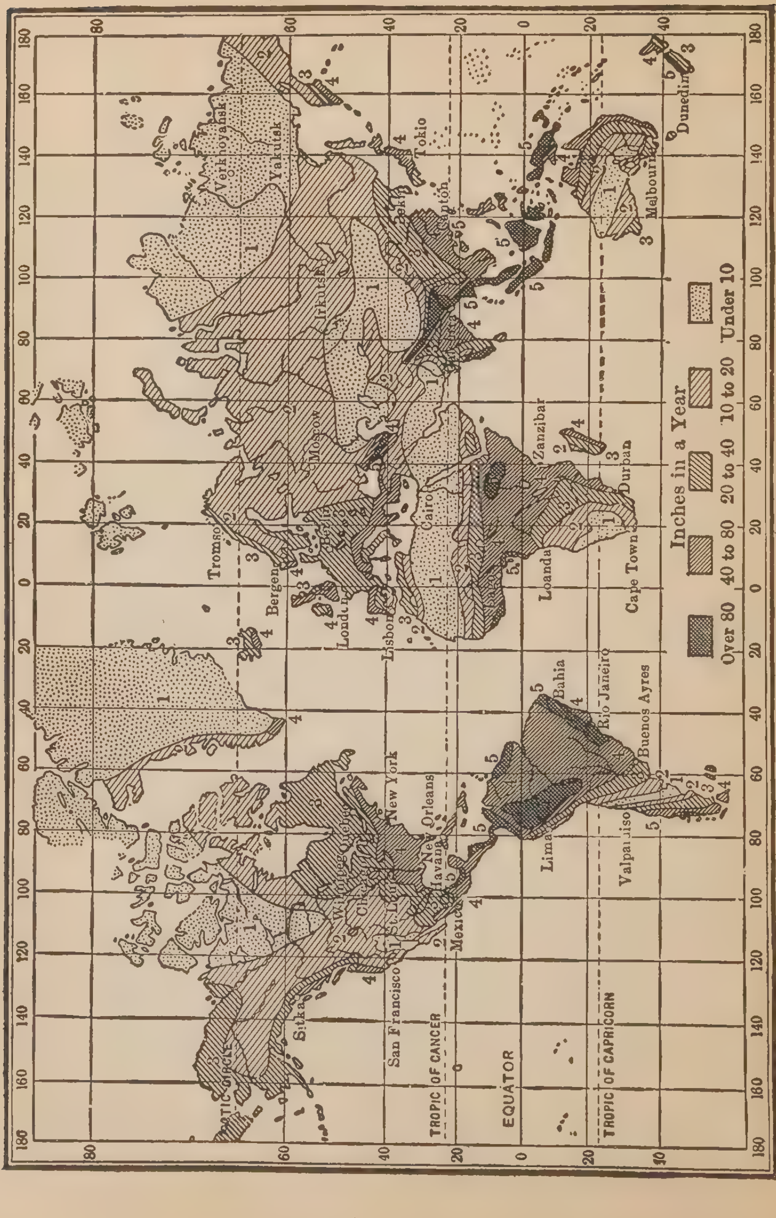


Fig 39. Map showing mean annual precipitation for the world.

Cascade mountains, the air descends and becomes warmer, and therefore dry. East of these mountains lie the arid and semi-arid lands of the Great Basin and of eastern Oregon and Washington.

When the westerly winds from the Pacific reach the higher parts of the Rocky Mountains, which are higher in many places than the mountains farther west, they again yield some moisture. But farther east, all the way to the Atlantic, these winds are dry, for they cross no more high mountains, and they do not generally go far enough north to reach a temperature as low as that of the mountains they have passed. For some distance east of the mountains the rainfall is slight; but east of central Kansas and Nebraska the lands are well supplied with moisture (Fig. 59). It is therefore clear that something besides the westerly winds brings rainfall to this region. This agent is the irregular *cyclonic wind*, to be studied in the next chapter.

The winds which blow from the Pacific to the continent in summer have a different effect upon rainfall. At this season, they find a temperature on the coastal lowlands higher than their own. They are therefore "dry" in this region, and give to much of California its dry season. Blowing inland, these winds reach mountains so high that the temperature is low enough to cause condensation and precipitation, even while the low lands to the west are dry. In Washington, the mountains near the coast are high enough to cause precipitation even in summer. In Alaska, where some of the mountains always are covered with snow, precipitation is heavy in summer, and at high altitudes much of it falls as snow.

Monsoon winds may yield much moisture. In general, they blow toward warmer regions, and so should be dry; but they may be forced up over high mountains, and precipitation follows. The heaviest rainfall on record, on the southern slopes of the Himalayas, is due to moonson winds. As in the case of the planetary winds, it is the windward sides of the mountains which receive the heavy precipitation from the monsoons. It is clear, therefore, that *the windward sides of high mountains are places of heavy rainfall and snowfall.*

Variation in rainfall. Some places which were once moist are now dry, as shown, for example, by petrified forests in the desert of southwestern United States. It is believed that a similar change in the past has made large areas of central Asia, formerly inhabited, too dry to support more than the scantiest population. In most places, the rainfall of corresponding months or seasons is rarely the same from year to year. These temporary variations are important

factors (1) in floods, which in some cases cause great damage to property and heavy loss of life (p. 237), and (2) in droughts, which frequently result in even greater loss through damage to crops, and in some countries, as India and China, through deaths from famine. Australia has more than once been crippled by long-continued, severe droughts. In the United States, with other conditions equal, the yield of corn depends directly on the amount of rain falling in June and July. When the amount is small, the crop is short. Other crops show similar close relations to rainfall. The importance of good crops to the prosperity of the country indicates that relative reliability of rainfall is a great national asset.

QUESTIONS

1. What effect do high altitudes have on the power of a steam engine?

2. Explain fully the effects on men (1) of a brisk wind, and (2) of calm air, in *summer*, in Louisiana. The same for *winter*.

3. Why are the westerly winds and trade-winds appropriately called *planetary winds*?

4. On which side of Lake Michigan is the lake-breeze stronger in summer? Why?

5. At what time of year would seasonal winds from Lake Michigan be most felt in Chicago?

6. How much force is exerted on the side of a house 60 feet long by 25 feet high, when a wind is blowing 90 miles an hour?

7. How do seasonal (ocean-continent) winds affect the temperature of the east coast of North America in summer? In winter? How do they affect the west coast at the two seasons?

8. In general, are winds stronger in California in winter or summer? Why?

9. Why are the most desirable residential quarters of many manufacturing centers in the United States located to the west and northwest of the city?

10. In what portions of the world would power from the wind be most reliable? In what portions of the land areas? Why? Where is it most likely to be utilized by man?

CHAPTER VIII

STORMS AND WEATHER FORECASTING

Weather Maps

Temperature, wind, rainfall (or snowfall), and cloudiness are the important elements in the weather of any place for any given time. As these elements are combined in different ways from day to day, the weather varies. Weather changes are important in so many ways that it is desirable, if possible, to know about them before they come. Thus winds of great velocity are dangerous to shipping at sea, and vessels, if warned of their coming, may remain in port. A freezing temperature in spring or autumn may cause losses amounting to hundreds of thousands, or even millions of dollars; but if due warning is given, it is possible in some cases to protect the crops which would be injured. In these ways and many more, weather changes and weather forecasting affect everyday life.

Since weather changes are associated directly with irregular winds (pp. 85, 90), and these in turn depend on pressure, it is evident that weather forecasting must depend largely on a study of pressure conditions. Changes of pressure from day to day have much more to do with weather changes than anything else has.

Isobaric lines (p. 67) and isothermal lines (p. 45) may be put on the same map, which may show also where the sun is shining, where it is cloudy, where it is raining, snowing, etc. Such a map is a *weather map*, and may be made for any region, to show the weather at any given time. Thus Fig. 40 is a weather map of the United States for January 9, 1911. Like all weather maps, it shows (1) isobars (full lines); (2) the direction of the winds (shown by arrows); (3) the degree of cloudiness; (4) areas of precipitation; and (5) isotherms (broken lines).

Weather maps for the United States are made by the Weather Bureau, a branch of the Federal Department of Agriculture. They are prepared in the chief cities, where telegrams are received twice daily from numerous Weather Bureau stations in different parts of

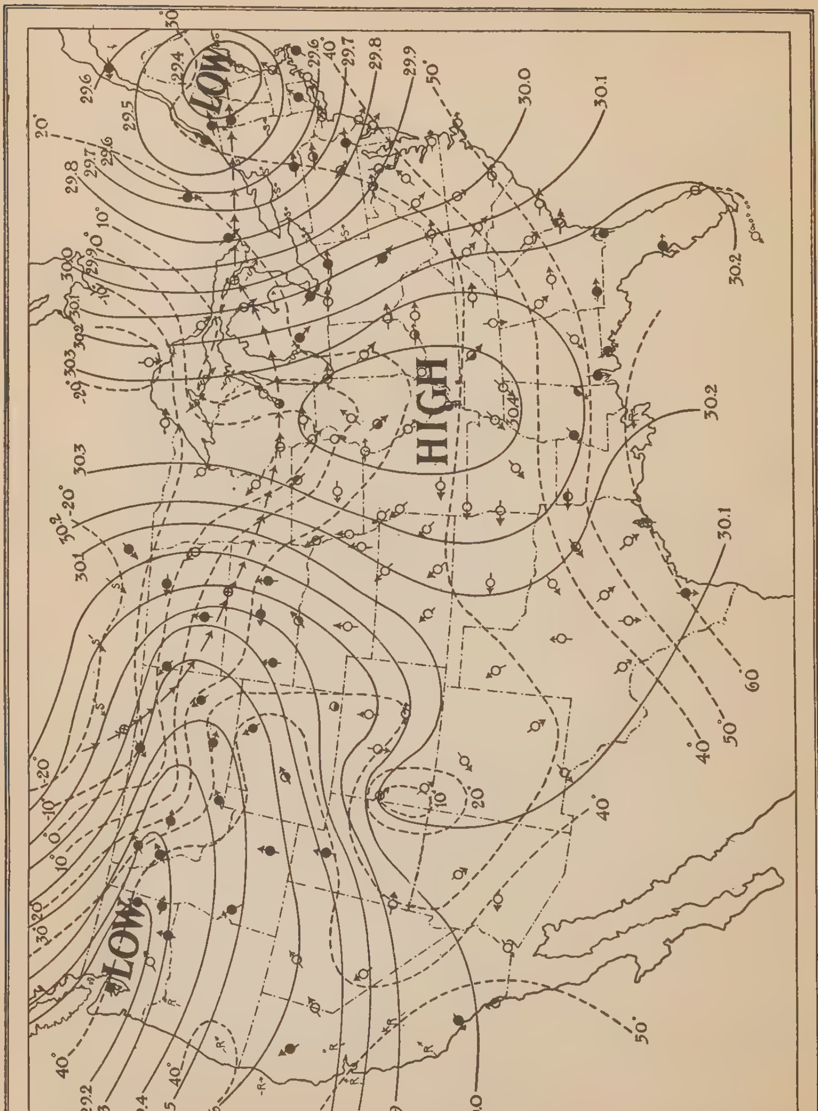


Fig. 40. Weather map for United States, January 9, 1911.

the country, telling the pressure, temperature, direction and velocity of the wind, cloudiness, and rainfall at the station whence the telegram is sent.

Explanation of the Map

(1) **Isobars.** The isobars of the map (Fig. 40) show a range of pressure from 30.4 inches in the area centering in the Mississippi Valley, to 29.4 in Maine, and 29.2 in Washington. The pressure is more than 30 inches in the central part of the country, and less than 30 inches on both the Atlantic and Pacific coasts.

The isobar of 30.4 in the central part of the United States is a closed line. The center of this high-pressure area is marked "high" (p. 66). West and east of the high the pressure decreases steadily toward the coasts, where there are centers of low pressure, marked "low" (p. 66). The minimum pressure in the low near the Pacific coast, 29.2, is less than in that over Maine, 29.4. Atmospheric pressures generally are unequal in different parts of the country. Hence most weather maps show both lows and highs, or at least one of each.

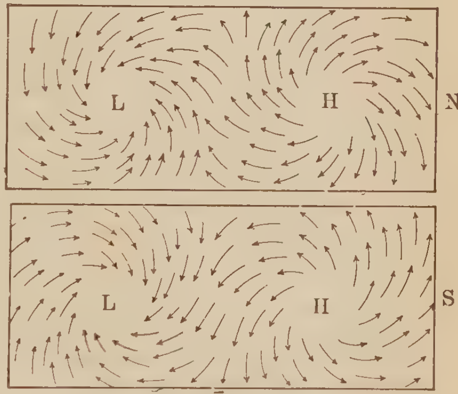


Fig. 41. Diagrams to show the circulation of air about a low, L, and a high, H, in the northern hemisphere (N) and the southern hemisphere (S).

(2) **Winds.** Wherever barometric pressures are unequal, winds are the result. The arrows on a weather map show the direction of the winds. On January 9, 1911 (Fig. 40), winds were blowing away from the high and toward the lows. The movements of air out from an area of high pressure constitute an *anticyclone,* and the movements in toward an area of low pressure constitute a *cyclone.* A cyclone is one type of *storm.* The winds in a cyclone are not always strong—rarely strong enough to be destructive. The violent wind-storms which are popularly called cyclones should be called *tornadoes.*

Winds do not blow straight out from the anticyclonic centers, nor straight in toward the cyclonic centers. They may *start* straight out from the center of each high, but in the northern hemisphere they are turned (deflected) toward the right (right-hand half of Fig. 41, N). Similarly, the winds which blow toward the cyclonic centers do not blow straight toward them, but are deflected a little to the right in the northern hemisphere (Fig. 40, and Fig. 41, N). In the southern hemisphere, the winds are turned to the left instead of to the right (Fig. 41, S).

The weather map tells nothing directly about actual wind velocities. This information appears in a table printed on the margin. But the strength of the winds at various points may be inferred from the map. In general, the winds are strong where isobars are crowded.

As air moves in toward the center of a cyclone, it also moves spirally up (Fig. 42). The outflow above is chiefly to the eastward,

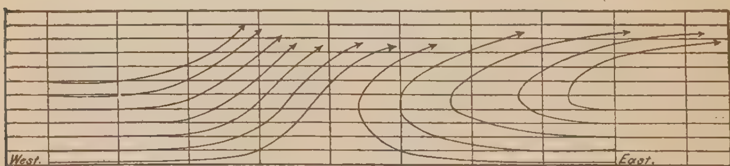


Fig. 42. Diagram illustrating the general movement of air currents in a cyclone of middle latitudes. The upper air moves mainly toward the east, in the direction of the prevailing winds.

the direction toward which the prevailing winds of middle latitudes blow. This upward movement has an important effect on precipitation (p. 85).

(3) **Cloudiness and precipitation.** An open circle on the shaft of an arrow (Fig. 40) indicates clear skies, a half-blackened circle (as in Wyoming) shows that the sky is partly cloudy, while a black circle (as in Montana) indicates general cloudiness. An *R* on the shaft of an arrow (as in California) indicates rain, and an *S* in the circle on the shaft of an arrow (as in New York) shows that snow is falling. Amounts of precipitation are given in the printed table with the other data for each station.

(4) **Temperature.** As indicated above, the broken lines of a weather map are isotherms. The isotherms of Fig. 40, and of the weather maps which follow, show two distinct features: (1) they

have little relation to parallels, and (2) all of them bend northward where the pressure is low, and southward where the pressure is high. These features are less pronounced on maps showing storms of less intensity.

Cyclones and Anticyclones

Characteristics of highs and lows. Highs and lows are sometimes much more pronounced than those shown in Fig. 40. In the low of Fig. 43 the pressure ranges from 29 at the center, to 30.1 in the East, and to 30.5 in the West. So great a range of pressure within the United States is uncommon. The isobars are closer together in this figure than in Fig. 40, and therefore indicate stronger winds. Cloudy skies prevail in the southeastern part of the cyclone.

Highs as well as lows may have great area. Fig. 44 shows a high, or anticyclone, more than 2,000 miles across, with a great range of pressure. The isotherms of this chart, like those of the preceding, stand in very definite relations to the isobars. Denver, in the anticyclone, is about 30° colder than the southern part of Maine, which is 3° farther north, but on the western border of a cyclone.

Near centers of low pressure, rain or snow falls in many cases, while around centers of high pressure there is, as a rule, no precipitation. The chief reason for rain or snow about a low is that the inflowing, rising air expands and is cooled (p. 60), and so gives up some of its moisture. In the northern hemisphere, southerly winds to the southeast of storm centers are, in general, blowing from warmer to cooler places, and this may result in rain or snow. The prevailing winds which control the outflow in the upper part of a cyclone (Fig. 42) tend to carry the rainfall to the east of its center.

The circulation of winds around cyclonic areas is the real factor in drawing moist air northward from the Gulf of Mexico, and in giving abundant rainfall east of the Mississippi River.

In an anticyclone there is a descending spiral movement of air. The descending air comes from an altitude where the air is colder than that at the bottom of the atmosphere, and hence brings a low temperature. Winds from anticyclones generally bring clear weather, but cold air moving down and out from an anticyclone may mingle with warm air about it, so as to cause some of the moisture of the latter to condense, giving rise to clouds, or even to precipitation.

Movements of cyclones and anticyclones. Highs and lows do not remain in the same place from day to day. This is shown by

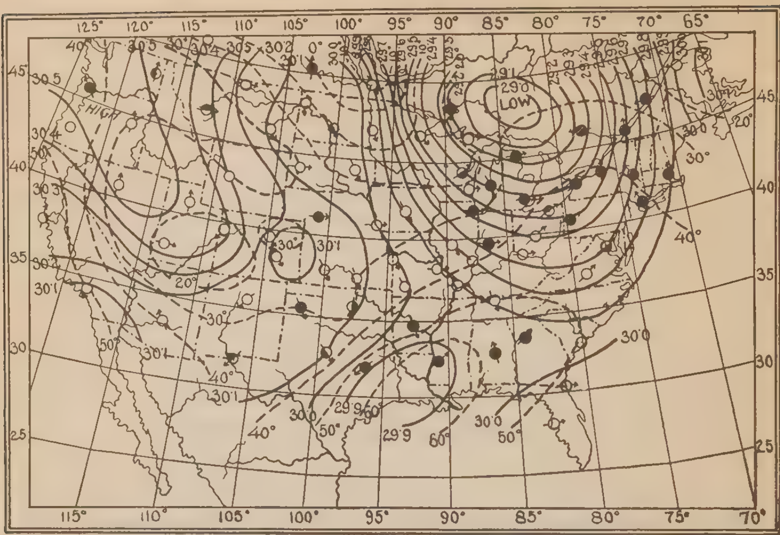


Fig. 43. Weather map for January 16, 1901, showing a very pronounced low.

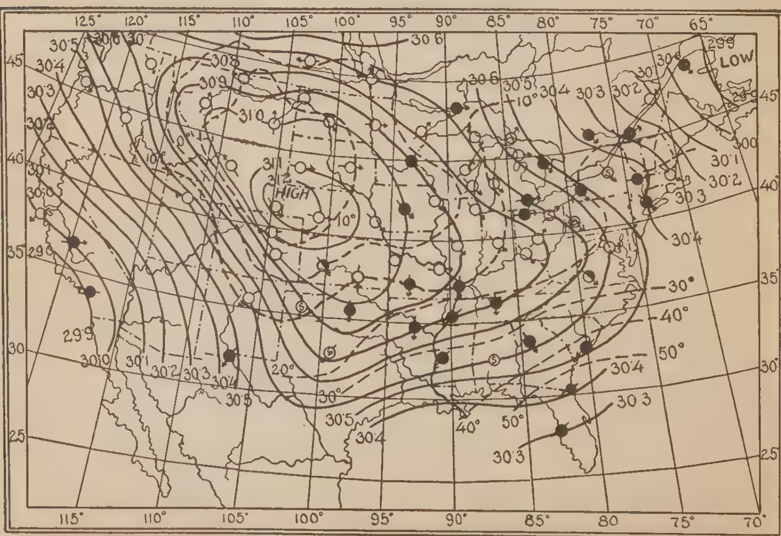


Fig. 44. Weather map for December 9, 1898, showing a high of great size.

Figs. 45–47, which are the weather maps of three successive days. In these figures areas of precipitation are shown by shading.

In Fig. 45 there is (1) a low along the Atlantic coast; (2) a high central over Iowa; (3) a feeble low north of Montana; and (4) a high in Oregon. The map of the succeeding day (Fig. 46) shows (1) that the low of the Atlantic coast has disappeared (moved to the east); (2) that the high of the interior has moved to West Virginia; (3) that the low which was north of Montana has moved to Dakota; while (4) the high of the Oregon coast remains about where it was. The map of the next day (Fig. 47) shows (1) that the high of the Virginias has

Fig. 45. Weather map for September 24, 1903. The shading on this and succeeding maps indicates areas of precipitation during the preceding 24 hours.

moved on, but not so far as on the preceding day; (2) that the low which was over North Dakota is now north of Lake Superior; (3) that the high of Oregon has moved east to Idaho and Montana; and (4) that a weak low has developed in Oklahoma.

The rate of progress of a storm is not the same as the velocity of its winds. The velocity of the wind depends on the differences in pressure. A weak cyclone, that is, one in which differences of pressure are not great, gives rise to weak winds, even though the center of the storm moves rapidly. A strong cyclone, that is, one in which the

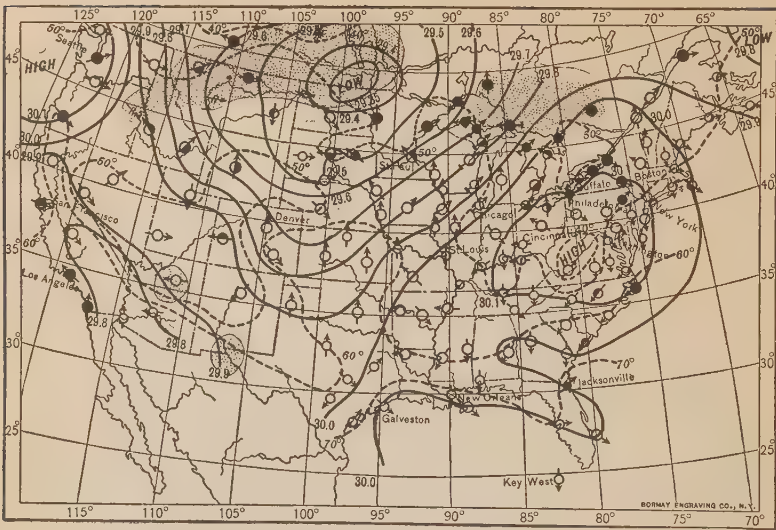


Fig. 46. Weather map for September 25, 1903.

Fig. 47. Weather map for September 26, 1903.

differences of pressure are great, gives rise to strong winds, even though the cyclone itself may move forward slowly.

The rate at which cyclones move varies with the season, the average being about 37 miles per hour in winter and 22 in summer. Storms may move at twice these rates, however, or at less than half their usual speed.

The course of a cyclone may be shown on a single map, as in Fig. 40. The row of arrows shows that the low of Maine has moved from western Canada. The mean tracks of cyclones and anticyclones

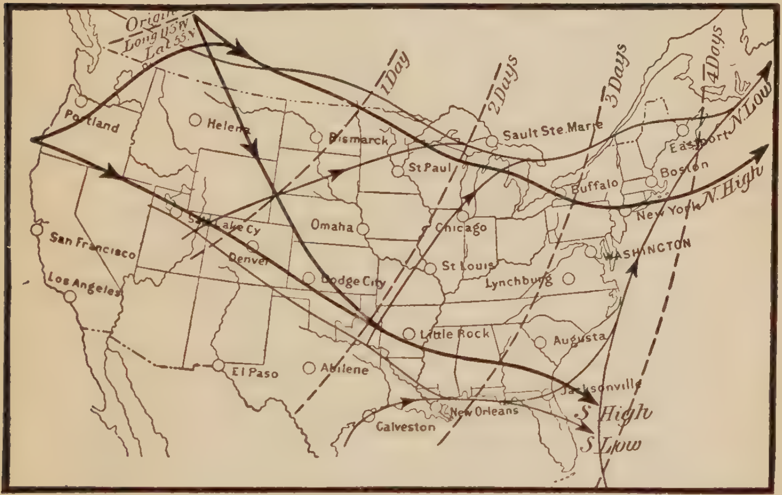


Fig. 48. Chart showing the mean tracks of cyclones (light lines) and anticyclones (heavy lines), and their average daily movement (broken lines).

for the United States are shown in Fig. 48. The broken lines on this map, marked 1 day, 2 days, 3 days, and 4 days, show the average daily progress of storms which come from the northwest.

Some anticyclones enter the United States from the Pacific, while others start north and northwest of Montana, or, at any rate, are first reported from there. Cyclones start in various places. Many of them appear first near the places where anticyclones start, but others appear first in Colorado, the Great Basin, Texas, and elsewhere.

The passage of a cyclone or anticyclone involves changes in the direction of the wind, and usually also changes of temperature,

humidity, and cloudiness. Thus in Fig. 46 the wind at St. Paul is southeasterly, though this city is in the zone of westerly winds. The next day, after the storm center has moved forward to a position northeast of St. Paul (Fig. 47), the wind is northwesterly. An east wind is often the first sign of an approaching cyclone; and since many cyclones bring rain, an east wind generally is taken as a sign of approaching rain throughout much of the United States.

Cyclones are, on the whole, more frequent and better developed in winter than in summer. They do not affect the air to great heights. Even when the great whirl or eddy is 2,000 miles across, its height (depth) is rarely more than 4 or 5 miles. The origin of the cyclones and anticyclones of middle latitudes is not well understood.

Winds and temperatures incidental to cyclones and anticyclones. During the passage of a cyclone, the air to the southeast of the storm center is drawn from warmer (lower) to cooler (higher) latitudes. In midsummer this often gives rise to a *hot wave*, though not all hot waves are associated closely with cyclones. Similar winds are known as the *sirocco* in the western Mediterranean region, and by other names elsewhere. In eastern United States, numerous sunstrokes and deaths from heat prostration accompany some hot waves in their progress across the country.

Air to the northwest of a cyclone moves from cooler (higher) to warmer (lower) latitudes. In winter, this may give rise to *cold waves*. These cold winds are known as *northers* in the southern part of the United States, and sometimes as *blizzards* in the northern part, though this name usually implies heavy snowfall and high wind, as well as low temperature.

When warm, moist air is forced up over mountains, it precipitates some of its moisture (p. 77). The precipitation sets free heat, so that the rising air is cooled much less than it would be otherwise. Beyond the crest of the mountains it descends, and is warmed in the process. It is warmed much more (often twice as much) in the descent than it was cooled in the ascent. It may, therefore, descend as a hot wind. Such winds are known as *chinook* winds in the United States, especially just east of the Rocky Mountains.

The chinook winds temper the rigorous winters of certain parts of the northwestern states and the Canadian provinces east of the mountains. They frequently evaporate a foot or more of snow in a few hours. For this reason they are sometimes called "snow-eaters." These winds make winter grazing possible over large areas which otherwise would be covered heavily with snow. Chinook winds

sometimes develop with great suddenness. In some cases the temperature has been known to rise 80° in six or eight hours under their influence.

The chinook winds of summer are sometimes so hot and drying as to wither vegetation, and occasionally to destroy crops.

Tropical cyclones. Cyclones sometimes start in tropical regions, and follow courses very different from those of the cyclones of middle latitudes. Most of the cyclones of this class which reach North

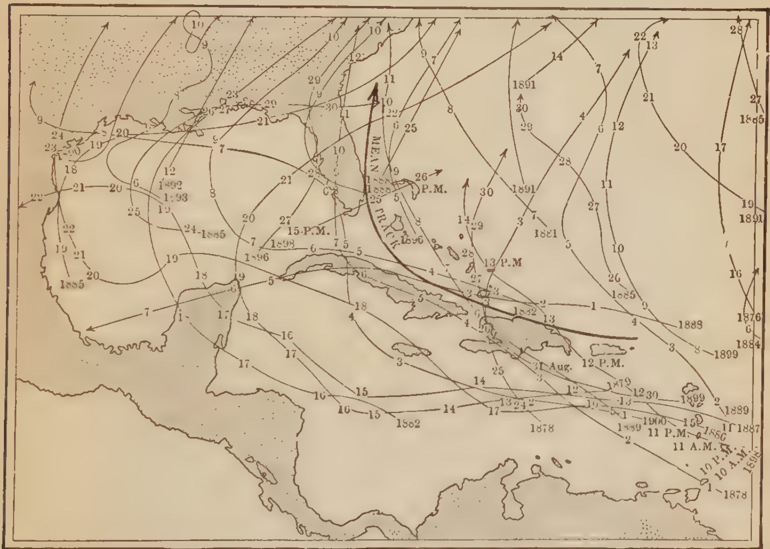


Fig. 49. Course of West Indian storms for August-October, 1878–1900. The heavy line indicates the mean track.

America originate in or near the West Indies, and they are most common in late summer and early autumn. They follow a northwesterly course until the latitude of Florida is reached. Here they commonly turn to the northward, and later to the northeastward, following the Atlantic coast. The heavy line of Fig. 49 shows the average path of tropical cyclones (*hurricanes*) for a period of years.

Tropical cyclones are stronger than those of intermediate latitudes; that is, the pressure at the center is lower and the winds are higher. Many of them do great damage along coasts, both to shipping and to low coastal lands. The great storm at Galveston in September,

1900, resulted in a loss of 6,000 lives, and damage to property estimated at more than $30,000,000. Much of the destruction was due to water driven by the high winds over the low island on which Galveston stands. An expensive sea-wall (Fig. 50) has since been built, and the level of the city raised, to prevent the recurrence of such a disaster.

In September, 1906, a West Indian hurricane swept the Gulf coast of Florida and Alabama, and then passed inland, with damage to shipping and crops estimated at 15 to 25 millions of dollars. Islands which lie near cyclone tracks suffer severely. Porto Rico, for example, has been devastated five times within the last century. The storm of 1899 was probably the worst. Coffee, sugar-cane, and tobacco crops were destroyed almost completely, more than 3,300 lives were lost, and the property

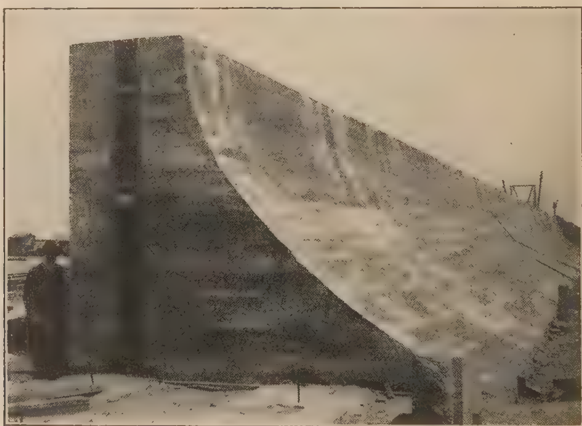


Fig. 50. A cross-section of the Galveston sea-wall, showing plan of construction and relative dimensions. The right-hand side faces the sea.

damage was estimated to be not less than $35,000,000. During this storm 23 inches of rain fell in 24 hours. These tropical storms are so violent that sailing vessels once within the storm's grasp rarely escape. For this reason there has been much careful study of these storms. Sailing directions, giving instructions how to escape from them, are now a part of the equipment of every vessel frequenting the oceans where tropical cyclones occur.

In the Atlantic, tropical cyclones occur north of the equator, though not south of it; in the Pacific, they occur both north and south. They occur in the later part of the hot season, and are believed to originate in strong convection (p. 38) currents. Fortunately tropical cyclones are much less frequent than cyclones of middle latitudes.

Weather Forecasting

Weather predictions. Weather predictions are based on the facts shown on weather maps. As a rule, official predictions are made only for the 36 or 48 hours immediately following the hour when the map is made. Take, for example, the map of the 25th of September, 1903 (Fig. 46). Rain accompanies the cyclone which is central over Dakota. Since this storm has, for the last 24 hours, been moving a little south of east at the rate of about 40 miles an hour, it is fair to presume that it will move in this same general direction at a similar rate for the next 24 hours. If, in this time, it advances to the Lake Superior region, it probably will bring with it weather similar to that which it is now giving to the region where it occurs. Hence, on the 25th, the prediction might be made that rain is to be expected in about 24 hours in the region around the head of Lake Superior.

On the 26th the prediction might be made that the low which is central north of Lake Superior (Fig. 47) will move on to the Gulf of St. Lawrence by the succeeding day, and that increasing cloudiness and rain will accompany it. Rain for the region about Lake Huron and the area east of it may, therefore, be predicted for the 27th.

Temperature changes as well as changes in cloudiness and precipitation may be predicted. Thus in Fig. 45 the isotherm of 50° bends southward notably in the high, central over Iowa. As the high moves east, it probably will carry the low temperature with it. Hence it is safe to predict that the temperature will fall in the area into which the anticyclone is to move. The map of the succeeding day (Fig. 46) shows that the temperature of western Virginia has fallen from about 60° to about 40° along the path of the high, while areas much farther north are warmer.

Fig. 46 also shows that North Dakota and Alberta have a temperature of 50°, that is, a temperature 10° warmer than that of western Virginia. It will be noted, too, that the relatively high temperature of Dakota, Montana, and Alberta goes with a low. As the cyclone moves eastward, the temperature along its path probably will rise. This is shown by the map of the next day (Fig. 47), which shows a temperature of about 50° north of Lake Superior. The same map shows how the isotherm of 40° bends to the southward in front of the high which is central over western Montana. As the high of Montana moves eastward, it will be likely to carry a low temperature with it.

From this map, therefore, it may be predicted that the temperature in Nebraska, Kansas, Iowa, and Missouri will be lower.

The time when the rain which a storm may bring to any given place will fall is calculated from the rate at which the storm is moving. In the same way, the prediction of the time of arrival of a cold wave which an anticyclone may bring is based on the rate of progress of the anticyclone. This rate is known in advance by telegraphic reports. Predictions concerning the weather may be made more readily for the central and eastern parts of the United States than for the western part, for the storms have been under observation longer before they reach the central and eastern states.

Failure of weather predictions. Weather predictions, even for short intervals, often fail. The reasons are many, among them the following: (1) Cyclones and anticyclones sometimes depart widely from the courses they commonly take. In such cases, the places the storm was expected to pass do not have the weather which was predicted for them. Thus a storm may be in line for St. Paul, to which it is expected to bring rain and a rising temperature; but instead of keeping its course, it may turn off to the northward, and the rain which was predicted for that city falls farther north.

(2) Storms change their rate of advance, and so arrive earlier or later than predicted. (3) Storms sometimes appear and disappear without warning. (4) A storm sometimes changes its character, becoming weaker or stronger. It then does not bring to the places it passes the weather predicted for them.

Value of weather forecasts. In spite of all mistakes, the warnings of storms, floods, cold waves, etc., sent out by the Weather Bureau, have been of great benefit. It has been estimated that property valued at $15,000,000 was saved in 1897 by warnings of impending floods. In 1910 the estimated saving was $1,000,000.

In September, 1903, vessels valued at $585,000 were held in ports temporarily, along the coast of Florida, by storm warnings. The loss of the Boston steamship *City of Portland*, with all on board, in the great storm of November 28, 1898, was due to a failure to heed storm warnings which kept all other craft in port. Warnings led to the protection of $1,000,000 worth of fruit about Jacksonville, Florida, in 1901, with an estimated saving of half this amount. Other warnings of cold in 1901 were estimated to have been the means of saving more then $3,000,000 worth of property. Shipments of perishable products, like most fruits, may be damaged badly if freezing temperatures are encountered unexpectedly in transit. Mer-

chants handling such products are saved much trouble and inconvenience by information from the Weather Bureau concerning the temperatures for which their shipments must be prepared.

The annual saving of property in these various ways exceeds, several times over, the total cost of the Weather Bureau.

Local Storms

Thunder-storms. Thunder-storms are frequent in the United States. They are most common in warm regions, and in warm seasons. Further, they are most common on days which are unusually warm, and during the warmer parts of these days; but there are occasional thunder-storms in the winter, and there are thunder-storms at night.

The first indication of a thunder-storm is usually a large cumulo-nimbus cloud, which, in the zone of the westerly winds, generally appears in the west. It moves eastward, and as it reaches the place of the observer, there is usually a smart breeze, or *thunder-squall*, rushing out before it. Shortly after the squall the rain begins to fall. The rainfall may be heavy, and the drops large, but the downpour does not usually last more than an hour, and in many cases much less. A second thunder-storm sometimes follows close upon the first.

Lightning is due to the discharge of electricity from one part of a cloud to another, from one cloud to another, or from the cloud to the ground. When lightning discharges approach the ground, they seek exposed objects in some cases and cause loss of property, chiefly through fire, and occasional loss of life. The thunder following the lightning is due to vibrations in the air caused by the electrical discharge. It sometimes happens that lightning at a great distance lights the clouds over a region where the electric discharge itself cannot be seen. This lighting of the clouds is often called *heat lightning*, because it is more commonly seen in hot weather than at other times. The *rainbows* which accompany or follow many thunder-storms are due to the effects of the drops of water in the atmosphere as the sun's rays pass through them.

In middle latitudes, most thunder-storms occur during the passage of cyclones, though they do not accompany all cyclones. They are more common on the south sides of cyclones than elsewhere, and many of them occur at a considerable distance from the center of the main storm. In middle latitudes, most thunder-storms move from west to east, while in the zone of trade-winds they move from east to west. In both cases they move with the prevailing winds. Much of the precipitation from summer cyclones is connected with thunder-storms. Hence localities having most of their rain during the warm season depend largely on thunder-storms for moisture. Not infrequently violent thunder-storms give precipitation in the form of *hail*.

Tornadoes. When a convection current is very strong, and has a very small diameter, the whirl becomes so intense in some cases as to cause great destruction. A whirling storm of this sort is a *tornado.* Tornadoes, like thunder-storms, are phenomena of hot weather. They are rather less abundant in the later part of the summer than in the earlier part. They are more likely to occur in a cyclone than in an anticyclone. Tornadoes are associated in most cases with hot days, and with the warmest part of the day.

The atmospheric pressure in the center of a tornado is usually much lower than in the center of a cyclone. In a very strong tornado, the pressure at the center may be a fourth less than that of its surroundings. This is one reason why the tornado is so destructive. During its passage, the pressure may be reduced from the normal amount, 14.7 lbs. per square inch, to three-fourths of this, or to 11 lbs. per square inch. If such a tornado passes over a closed building in which the air pressure is 2,117 lbs. per square foot, the pressure on the outside becomes 1,584 lbs. The walls are therefore pushed out with a force of 533 lbs. per square foot, and unless they are very strong, they will fall, as if the building had exploded. In some cases only the weaker parts, such as windows, yield.

Fig. 51. Funnel-shaped cloud of a tornado, Solomon, Kas. (U. S. Weather Bureau.)

Not only is the pressure at the center of the tornado very low, but the area of the low pressure is very small. While a cyclone may be 1,000 miles or more across, few tornadoes exceed 1,000 feet in diameter at the surface of the land, and many are only a few yards wide. The result is that the winds are violent. Estimated by the size and weight of the objects moved, their velocities have been thought to reach 400 or 500 miles per hour. With this velocity, or even a velocity much less, trees are overturned, buildings unroofed or blown down, and bridges hurled from their foundations.

A tornado is often seen first as a funnel-shaped cloud (Fig. 51), the point of which may be far above the ground. As the funnel moves forward, its lower end may rise or fall. The cloud is due chiefly to the condensation of moisture in the sharp convection current, and the funnel shape is due to the expanding and spreading of the air as it rises.

The tornado is, of all storms, the most destructive, but, in most cases, it has a very narrow track, and does not work destruction for a very great distance, rarely more than 15 to 30 miles.

One of the most destructive, though not one of the most violent, tornadoes of recent times was that at St. Louis, May 27, 1896. It accompanied a thunderstorm in the southeastern part of a cyclone, central some distance northwest of the city. The destruction of property in and about St. Louis was estimated at about $13,000,000.

A more violent tornado was that at Louisville on the 27th of March, 1890, just before nine o'clock in the evening. Many weak buildings were wrecked, 76 persons were killed and about 200 injured in Louisville alone, and the loss of property was estimated at about $2,500,000.

Questions

1. Explain the apparent contradiction in the fact that northeast winds, in most areas of the United States, are part of a storm coming from the west.

2. Show by a series of diagrams, in their proper order, the weather changes which would take place at a given station on three successive days under the following conditions: (1) On the first day the storm center (low) is approaching from the southwest; (2) on the second day at noon the center is 200 miles away, directly to the south; (3) on the third day it has moved on in the normal direction, and at the normal rate. Diameter of the low, 1,000 miles.

Make similar diagrams for the same place for a storm following a track 200 miles to the north of the station.

3. Make rules for forecasting temperature when the weather map shows isotherms running (1) east and west, and far apart; (2) north and south, and close together.

4. Indicate what truth, if any, there is in the following weather proverbs: (1) "Too cold to snow." (2) "A white frost is a sign of a fair day to follow." (3) "Rainbow in the morning, sailors take warning; rainbow at night, the sailors delight."

5. Suggest other weather proverbs which you have heard, and show whether or not they have any basis of truth.

6. Why are large dealers in grains, cotton, and tobacco interested in the daily weather map?

7. Suggest some of the changes in the climate of the United States which would result (1) if the Rocky Mountains ran east and west, along the entire length of the Canadian boundary; (2) if the area of the Gulf of Mexico were land.

CHAPTER IX

TROPICAL CLIMATE

Extent of tropical regions. The tropical zone, as usually defined, is limited by the tropic of Cancer on the north and the tropic of Capricorn on the south. Other definitions of this zone have been suggested, as (1) the zone where the trade-winds blow, and (2) the zone where the palm tree grows, the palm being taken as the type of tropical vegetation (Fig. 52). Defined by parallels, the tropical zone covers about two-fifths the area of the earth.

About one-third of all the land — in round numbers, 17,000,000 square miles — is within the tropics. This third of the land supports about a third of the people of the earth — in round numbers, 500,000,000. Much tropical land is desert, and much is covered with dense forests (Fig. 53), and these parts are but sparsely peopled; but the fertile areas which are cultivated support dense populations. In Java, for example, 30,000,000 people live in an area two-thirds that of Pennsylvania. About one-seventh of North America and one-sixth of its people are in the tropics. The tropical part of South America is much larger, nearly three-fourths of the continent and of its people being between the Caribbean Sea and the tropic of Capricorn. No part of Europe is in the tropics, and only about one-fifth of Asia is tropical, but this fifth supports fully half the population of the continent. Three-fourths of Africa are in the tropical zone and two-thirds of its people, and about half of Australia and one-fourth of its people.

The area of ocean within the tropics is about 70,000,000 square miles. The large proportion of water in this zone gives much of the land a marine climate. Relatively small areas, in the wider parts of the continents, show true continental conditions.

General Characteristics of Tropical Climates

The most striking thing about the climate of tropical regions is its uniformity. The weather does not change frequently, as in middle latitudes. Atmospheric conditions are so nearly uniform

month after month that weather and climate are almost the same. Now and then hurricanes and typhoons occur in some parts of the zone.

Uniformity of temperatures. The temperatures of the tropics are even more uniform than the other elements of climate. (1) The noon altitude of the sun varies much less than in other zones, and (2) the length of day and of night is always nearly the same. As a result, the amount of insolation never varies much, and since it is always large, the temperature is always high, except at high altitudes.

Annual changes. Many tropical places have a range of less than 10° between the mean temperatures of the warmest and coldest months, and a range of less than 15° is characteristic of most tropical lands. On the oceans, and on some lands, the range is insignificant. At Bogota, Colombia, the coolest month is less than 3° cooler than the warmest. Buitenzorg, Java, has an annual range of only 1.8°. Toward the edges of the tropical zone, the annual range of temperature is greater, especially inland. Thus at Nagpur, in the interior of India, Lat. 21°9′, the range is 27.1°.

Diurnal changes. In many parts of the tropical zone, the difference in temperature between day and night is greater than that between the warmest and the coolest months. Near coasts, the temperature rarely falls below 70° at night, or rises above 90° by day. Inland, the range is much greater, and in dry regions far from coasts it is as much as 60° or 70° in some places (from 50° or 60° at night, to a maximum of 120° by day). In places,

Fig. 52. Map of the tropical regions, showing land and water areas. Poleward limit of distribution of palm trees ——. Poleward limit of trade-winds .... Mean annual isotherm of 68° F. - - - - -.

Fig. 53. Map showing distribution of types of vegetation in tropical lands. (Diercke.)

freezing temperatures have been known at sea-level, as in deserts near the margins of the zone. Since the daily range is several times as great as the range between the warmest and coldest months, it is a common saying that "night is the winter of the tropics." The daily range is much the same day after day.

On the whole, the highest temperatures of the tropics are no higher than those of middle latitudes. It is not so much the high temperature, as the *continued high temperature*, which distinguishes tropical climate.

Effects of temperatures. Seasonal changes of temperature are so slight that they have little influence on life — animal or plant. The likeness of one day to another, and of one month to another, is probably a chief cause of the habit which tropical people have of putting off everything possible until "tomorrow."

In some parts of the tropical zone, high temperatures are associated with high humidity. This means a *high sensible temperature*, which is uncomfortable and harmful in various ways. Sunstrokes and heat prostrations are especially common among white people. The high temperature and humidity are also unhealthful, and together constitute one of the greatest obstacles to the life of white men in this zone. The dampness and heat are enervating, as illustrated by the general laziness of tropical natives (p. 337) — a trait which appears sooner or later in most white people who remain in this zone.

One of the most important results of the high temperature of tropical regions is that it permits vegetation to grow throughout

the year, where rainfall is sufficient. Many trees bear buds, blossoms, and ripe fruit at the same time.

Variability of rainfall. The *variability* of tropical rainfall is in contrast with the *uniformity* of the temperature. Some places are always dry, and others always rainy. In some places there is no rain for months at a time, and almost daily rains during the rest of the year. Some places have one rainy season each year, while others have two. This variability of rainfall is the controlling factor in the climate where the other leading element, temperature, is nearly constant. In general, the variations of rainfall are definite and regular.

The distribution of rain in the tropics is influenced by (1) winds, and (2) topography. The winds (and calms) most important in determining the distribution of rains are (a) the *trade-winds*, and (b) the *equatorial calms* (p. 74). The calm belt moves north and south after the sun (p. 14), and its movement affects the position and extent of the trade-wind belts. The periodic character of rains in this zone depends, therefore, mainly on the apparent movement of the sun north and south of the equator.

Seasons of rainfall. For most places within the limits of the migrating belt of calms, the rain comes when the sun is nearly overhead, or a little later. In the trade-wind zone, as elsewhere, rain is likely to fall from air forced up over high elevations (p. 77).

The distribution of rainfall through the year gives a basis for the division of the year into seasons. Some places have two seasons, one rainy and one dry, while others have four seasons, two rainy and two dry. The lengths of these seasons vary much from place to place.

Effects on life. Rainfall is here the chief factor controlling the distribution of life, and many of its relations. This is illustrated (1) by the rapidity with which vegetation springs up when rain begins after a long dry season; (2) by the fact that over millions of square miles the planting of crops depends on the coming of rain; and (3) by the further fact that even the nesting of many birds takes place only in the rainy season.

Types of Climate within the Tropics

Rainfall and its effects furnish a basis on which different types of tropical climate may be distinguished. There are four principal types: (1) The *equatorial type*, affecting a zone of 10° to 15° on either side of the equator; (2) the *trade-wind type*, affecting belts be-

tween the equatorial zone and the tropics of Cancer and Capricorn; (3) the *monsoon type*, especially about lands near the sea; and (4) the modification of these types produced by high altitudes, giving what may be called *mountain climate.*

1. Equatorial Climate

Temperature. Temperature is least variable in the equatorial part of the tropical zone. The differences of temperature here depend chiefly on (1) nearness to the sea, especially nearness to that sea from which the wind blows to the land, and (2) altitude. The typical marine climate of this belt has almost no change of temperature from month to month. Thus Batavia, the capital of Java, has a mean annual temperature of 78.8° F., and the coolest month is only 2° cooler than the warmest. In the interior of central Africa, on the other hand, the mean annual temperature may be the same as that at Batavia, but from the warmest to the coolest month the range is 10° or 12°.

The daily range of temperature is almost always greater than the annual range. Quito, Ecuador, Lat. 0°14′ S., at an altitude of 9,350 feet, has an annual range of less than 1°; but throughout the year the temperature in early morning is about 47°, while at midday it is about 66°. On coasts and low islands in similar latitudes, the daily range is less, say from 90° to 75°. People living under the latter conditions are very sensitive to marked changes of temperature, and for them a temperature much below 70° may mean actual suffering. Frost on low lands near the sea is unknown.

Rainfall. The rains come, for the most part, in daily showers. Even during the season of greatest rain, almost every day has a clear morning, and the rain comes from thunder-storms in the afternoon. In many places they come with marked regularity at a certain hour in the afternoon.

The migration of the belt of calms involves the movement of the zone of daily thunder-storm rains. All places alternately in and out of the belt of calms have wet and dry seasons. Near the borders of the equatorial region there is one short wet season and one long dry one. In the central part of the region there are two wet and two dry seasons, but the latter are not so dry as those farther from the equator.

The rainfall of places near the margin of the equatorial belt is illustrated by that at Cochabamba, Bolivia, 17° 20′ S., which has plentiful rain during its summer (December to February), and a nearly rainless season from the middle of March to the middle of November.

North of the equator, in the latitude corresponding to that of Cochabamba, the rainy season begins in May or June, and continues until September or October. Since there is little difference in temperature between the various months of the year, the value of rainfall for crops is about as great at one time as another. On the whole, rainfall near the equator is (1) more, and (2) less variable in amount, time of coming, and duration, than rainfall nearer the borders of the equatorial belt. As a rule, the farther a place in this belt is from the equator, the shorter its rainy season.

Humidity and cloudiness. Humidity is high, as a rule, during the rainy season, and low during the dry season. While continued high humidity has bad effects on tropical people, as already pointed out, it favors heavy dews, which may be of great benefit where rainfall is scanty. Cloudiness is common during the rainy seasons, and where there are two rainy seasons, there may be cloudiness 70 or 80 per cent of the time.

The distribution of rain and clouds throughout the year affects the temperatures of the different months. As a rule, the end of the dry season has the highest temperature, and the rainy season is, in many places, the coolest part of the year, though the sun is then highest. This is due to the fact that the clouds shut off the sun's rays for a considerable part of the day. The increased humidity of the rainy season may make its sensible temperature higher than that of the hotter dry season. In many places, therefore, the rainy season is the most disagreeable time of year. Some tropical diseases are also most prevalent then.

Moist equatorial climate and life. The high temperature of this zone and the abundant rainfall of its central portion favor a luxuriant growth of vegetation. Dense forests, such as those in the Amazon Valley, in central Africa, and in the Malay Peninsula, are characteristic of the humid parts of the zone. These forests are inhabited only by relatively sparse populations of backward natives, who live chiefly by hunting and fishing, and on the food supplied by the forest (pp. 337-339).

The moist equatorial climate is unhealthful, especially for white people. Tropical malaria, yellow fever, and intestinal disorders are the worst enemies which the white man meets near the equator. All these reach their maximum during the rainy season. The first two are spread by mosquitoes, and consequently are associated with wet, swampy places.

Along the Amazon Valley, and especially on the equatorial coast of Africa, fevers almost control the location of residences for white settlers. If the white man escapes the fevers, there is still the climate itself with which he must contend. The never-varying high temperature, and the excessive moisture month after month, with never any stimulus from invigorating cold, gradually have their effect. Tropical anæmia appears sooner or later in most cases, and unless he seeks relief in a colder climate, the white man loses his physical and mental vigor.

It is necessary to employ a force of men simply to keep the tracks of some tropical railroads clear of vegetation. Many wagon roads become impassable in the rainy season, and at these times a mud sledge, hauled by the water buffalo, is used in some regions, but it is a very primitive and unsatisfactory mode of conveyance. During the rainy season the rivers are swollen, and travel by boat is easier than at other times, for great sections of country are then flooded.

Wooden railroad ties and telegraph poles decay rapidly, and it is necessary, in building railroads in parts of the tropics, to use special woods, which do not decay readily, or to substitute iron and concrete. The effect of all these things is to retard commerce. The most favored localities for trade in equatorial regions are those where a large river offers a natural trade route, and the river port is therefore the commercial center. Para and Manaos, on the Amazon, are examples of cities developed by river traffic through an equatorial forest. The commodities handled are largely forest products (p. 339).

Dry equatorial climate and life. Toward the borders of the region of equatorial climate the absence or scantiness of rain through most of the year leads to vegetation very different from that nearer the equator. Grass lands replace dense forests (Fig. 53), the *llanos* of Venezuela, the *campos* of Brazil, and the *Sudan* of Africa, being good examples. These regions are without large forests, since the period of growth, limited chiefly to the rainy season, is too short for trees. Scattered patches of forest, however, occur here and there, as in the campos of Brazil.

The people of the grass lands are more advanced than the forest-dwellers nearer the equator. They get much of their living from flocks and herds. The necessity of moving frequently to find new pasturage for their cattle, goats, or camels, makes many of these pastoral people nomadic.

In favored places, especially where irrigation is possible, the people become permanent settlers, and cultivate the soil. Outside the irrigated lands, crops are planted to some extent, but only in the rainy season, and only where the rainfall is considerable. Sometimes the rain fails to come at the expected time, or in the amounts expected. This uncertainty has retarded the development of agriculture, and has led to frequent famines.

Irrigation may yet make productive much dry land in this climate. Here white men may live with more comfort than nearer the equator, for the low humidity during much of the year is more healthful, and makes the high temperature easier to bear. The llanos

of Venezuela, the campos of Brazil, and the African Sudan are therefore important regions with respect to future development.

2. *Trade-Wind Climate*

Winds and temperature. The most striking feature of the trade-wind climate is the steadiness of the winds, which blow with a velocity of 10 to 30 miles an hour throughout the year. The steady winds make the temperature conditions simple, especially over the oceans, and the climate of islands which lie in the trade-wind zone is about the simplest in the world.

Both annual and diurnal changes of temperature are greater than in the equatorial belt. Low lands swept by the trades tend to be arid. They are warmed rapidly by day, and cooled rapidly at night, having in many places a daily range of 50° or 60°. Temperatures as low as 32° are not unknown. These great changes are felt less than equal changes near the equator, because the humidity is low. The drier air with its greater changes of temperature makes the arid and desert lands more healthful than moist equatorial regions. In some ways the desert climate is invigorating, and diseases common in the equatorial regions are rare in many trade-wind districts. Man does not encounter the same kinds of difficulties, therefore, as in the equatorial regions.

Rainfall. Though commonly drying winds, the trades contain much water vapor, and become wet winds when cooled to the dew point. They are not so cooled over low lands, hence the latter are dry as long as the trades blow. Where they blow throughout the year, the land is desert (Fig. 39). On the other hand, where the trades blow over high lands, the ascending air is cooled, and clouds may form and rain fall. For this reason, the windward sides of highlands in the trade-wind belts are likely to be rainy, while the leeward sides are dry (Fig. 39). The leeward (westward) side of the Andes, from Ecuador to northern Chile, presents the strange spectacle of a coastal desert, and a similar condition is found on the leeward coast of southwest Africa. Highlands standing in mid-ocean also have a rainy side toward the trades, and a drier side in the lee, as illustrated by the Hawaiian Islands.

In Australia (Fig. 54), a continuous highland lies close to the east coast, directly across the path of the southeast trades. The effect of this barrier is to increase the area of the interior desert, sometimes called the "dead heart of Australia," and greatly to restrict the spread of population (Fig. 55).

The importance of high lands in getting rain from trade-winds is seen in the fact that rain falls and vegetation flourishes (p. 334) on local elevations in the Sahara. Streams flow for short distances from the mountains, but soon dry up or are absorbed into the sands of the desert below.

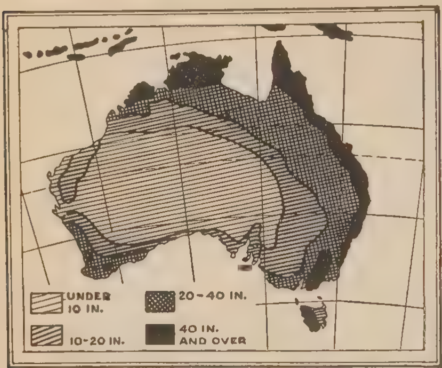


Fig. 54.

Fig. 55.

Fig. 54. Mean annual rainfall for Australia. (Diercke.)

Fig. 55. Map showing density of population per square mile in Australia. (Lyde.)

Most low lands affected by the trades are, on the whole, sunny, and trade-wind deserts are almost cloudless. This fact may have significance in the future, in the possible generation and storage of power derived from the heat of the sun's rays. Cloudiness is confined chiefly to windward slopes, which form but a small part of the total area of the trade-wind zone.

The time of the rains in the trade-wind belts varies from place to place. In some places it is distributed somewhat evenly throughout the year; in others it is seasonal. Places which get rain from the trade-winds have no rainless season if the winds are steady throughout the year, as in the central parts of the trade-wind zones. The trade-wind type of rainfall is modified in latitudes low enough to be reached by the equatorial calms. Trade-winds are interrupted in some places by monsoon winds (p. 75), and where this is the case, they may modify rainfall conditions.

Cyclones. The normal weather conditions of trade-wind belts are in places interrupted by tropical cyclones. They appear to origi-

nate along the margins of the equatorial belt, and move to higher latitudes through the trade-wind zone (Fig. 49). They occur during late summer and early autumn only. They interfere with the regular daily changes of temperature, and in many cases they give torrential rains.

Trade-winds and commerce. The steady, reliable trade-winds, which prevail over a wide east-west belt of the oceans, have long helped to determine the courses of sailing vessels, whose routes, going and coming, are different.

Whaling vessels out-bound to the Pacific from New Bedford commonly went across the Atlantic to the Cape Verde or Canary Islands before turning south. Vessels in-bound from the Pacific to New England usually swing around Cape Horn, far out into the South Atlantic (Why?), and then sail directly home. The Panama Canal will be of little importance to *sailing* vessels going east, on account of adverse winds. Similarly, the Red Sea presents head winds to sailing vessels going from the Indian Ocean to the Mediterranean. Unlike sailing vessels, steamers generally follow about the same course in both directions.

Trade-wind climate and life. Temperature conditions are almost as favorable for vegetation in the trade-wind zone as in the equatorial belt, but moisture is scanty. Forests as dense as those in equatorial climates occur on the windward slopes of some mountains. Most low lands in the zone of trades are arid. The Sahara, more than two-thirds the size of the United States, is an example.

Considering the tropical zone as a whole, vegetation decreases in amount from the equator out (Fig. 53). This is illustrated well in Africa, which extends well beyond the tropics both north and south of the equator. Near the equator, there is the dense equatorial forest, and on either side of it are belts of grasses, developed best in the Sudan. North of the Sudan is the Sahara, with little or no vegetation. South of the equator, in the area corresponding to the Sahara, the continent is narrower and the land higher, so that desert conditions are not as fully developed.

Human life in the desert is controlled mainly by the climate (p. 332). Vegetation is so scanty that the people, depending for support mainly on a few animals, must move frequently from one source of water to another. Deserts interfere in many ways with travel and communication among men, and a desert is almost as effective a barrier as an ocean to plants and animals (p. 331). Few beasts of burden can stand desert conditions, and caravan trade is carried on chiefly with the help of camels (p. 331). Food and useful materials of all kinds are scarce, yet the great daily changes of temperature

necessitate more clothing than is needed nearer the equator. White clothing is worn most, because it absorbs less sun-heat than dark fabrics. The clothing is loose, partly because such clothing is more comfortable in the heat, and partly because the danger of dust-storms makes it desirable to have a covering which can be drawn over the head quickly (p. 201). The people of deserts usually live in tents, or in loosely built, low, flat-roofed houses. There is no need for shutting out cold or rain, and when strong, the flat roofs are good places to sleep.

Since fuel is scarce in the desert, cooking is of the most primitive sort. Much of the little meat used is air-dried. Utensils, such as vessels for holding water, are made of leather — about the only serviceable material to be had in many places.

In parts of the deserts, showers occur now and then. In some places they come regularly at certain seasons of the year, and, in favored spots, the rainfall is enough to grow grain. In this case, the rainfall has a marked effect on the customs and religions of the people. In some places elaborate ceremonies are performed in honor of the rain gods before seeds are planted. The worship of rain, of rain clouds, or of the gods supposed to control them, is common. Sun worship is also common, for the sun is one of the most prominent things of the desert.

3. *Monsoon Climate*

Rainfall. At the season when the sun's altitude is greatest, the trade-winds are overcome, in some places, by the tropical monsoon (p. 75). While the monsoon lasts, it may blow very steadily.

Monsoons are well developed in southern and southeastern Asia, especially in India and thence to the China Sea. On the eastern coast of Asia, northward nearly to latitude 50°, there is a somewhat similar wind from the ocean in summer, which gives some rain to the land. For most places in the northern hemisphere, the monsoon season is between May and October. In the southern hemisphere, especially northern Australia, it is from November to April. The monsoon wind generally brings rain, and heavy rain on the windward sides of high mountains. A fall of 400 to 500 inches a year occurs in a few places. Since it all falls in four or five months, this means a daily rainfall of two to four inches throughout the rainy season.

The Indian monsoon is a southwest wind, blowing from the Indian Ocean and the Bay of Bengal. Western and southwestern slopes therefore receive much rain, while the eastern coast, in the lee of the

Deccan plateau and Eastern Ghats, gets little rain while the monsoon blows. This coast gets its rain when the northeast trade-wind blows. In northwestern India there is a large desert, not reached by the monsoon. Hence different parts of India have different types of rainfall, largely as a result of the relation of wind direction to topography.

The conditions which produce rain mean increased cloudiness, and so the rainy season may be less hot than the others. As a rule, the highest temperatures occur just before the rainy season begins, for at this time the regular winds become weak or fail altogether. During the rainy season, the increased humidity more than offsets the comfort which the slightly lower temperatures might afford.

Northern Australia (Fig. 54), and the northern coast of the Gulf of Guinea, in west Africa, have distinct tropical monsoon climates, but there are no important monsoon districts in the tropical lands of the western hemisphere, because the arrangement of land and water does not favor their development.

Importance of monsoon rains. Monsoon lands afford rather easy conditions of life, so far as the needs of man are concerned, and they contain the larger part of the population of the tropical zone. India alone has 300,000,000 people, in an area less than two-thirds that of the United States.

The importance of the monsoon rain to southern Asia can hardly be overemphasized. During the dry season all vegetation withers, and the earth is parched and dusty. Hence the growing of crops and the support of the people over vast areas depend on the regular appearance of the rain-bringing monsoon. For one reason or another, the monsoons sometimes fail; still oftener they do not appear when they should, or stop sooner than usual; and finally, they are sometimes interrupted during what should be their proper season. The failure of the rain means loss of crops and famine for the dense populations of the monsoon districts. Famines usually leave hundreds of thousands of people in a weakened condition, so that ravages of epidemic diseases, like bubonic plague and Asiatic cholera, commonly follow a famine. In India, deaths from famine and disease have exceeded a million in a single year. So great has been the loss of life, in some cases, that laborers enough to cultivate the farms were not left. The regions of famine are the regions of moderate rainfall (30 to 50 inches), where, in normal years, there is water enough for the crops. In other places, especially in southern China, too much rain sometimes brings disaster. Rivers rise high above their banks, destroying property and life; and famines resulting from the destruction of crops, at times cripple whole provinces.

4. *Climate in High Altitudes*

Effect on temperature. For most of the tropical zone, varying altitude is the one factor which causes important variations in tem-

perature. The extent of this variation is suggested by the fact that tropical mountains exceeding 16,000 feet are snow-capped.

The lower temperatures found at moderate altitudes make plateaus in the tropics more agreeable and healthful than lowlands. On the Bolivian plateau, for example, the daily temperature may range from 32° to 75° or 80°. White people living in the tropics seek the highlands, whenever possible, for residence (p. 320). The effect of the lesser heat even at altitudes of 7,000–8,000 feet is not, however, equal to an invigorating cold season, like the winter of middle latitudes. The climate of tropical mountains and plateaus is somewhat like the marine climate of the temperate zones.

Vegetation and altitude. The vegetation, native and cultivated, of the higher altitudes of the tropical zone resembles that at lower levels outside the tropics. For example, on tropical highlands in Bolivia wheat and potatoes are common crops, whereas on most tropical lowlands they cannot be grown at all, or not as profitably as rice. There is a gradual change with increase of altitude, from products like sugar-cane or rice on the lowlands, through a belt of temperate-zone fruits or vegetables at a moderate altitude, to cold-temperate and Arctic types of plants, and then to perpetual snow at an elevation of about 16,000 feet. The snow and ice on the heights help to supply water for irrigation below. In places, too, the ice of the high mountains is carried down to settlements below.

Population and altitude. An important effect of the highland temperatures is seen in the distribution of the population. From Mexico to Bolivia, most of the highlands are well populated, and the lowlands sparsely (Fig. 56). The single exception is Peru, where three-fourths of the people live on the coastal lowland, which is dry and healthful. Many of the chief cities are at elevations exceeding 5,000 feet.

In tropical America, it is common for the chief city to be on the highland in the interior, and for a smaller city, serving as a commercial outlet, to be on the hot, damp plain close to the sea. Mexico City and Vera Cruz, Caracas and La Guayra, São Paulo and Santos, are examples. Outside the cities, the highlands are the most thickly settled and the best developed sections, while the lowlands have few people, chiefly natives, and are but little developed. The result is that many of the chief products of tropical countries are not really tropical in character.

The decreased pressure of air which goes with increased altitude is of some importance in the higher tropical lands. As a rule the natives living at high altitudes (in Bolivia up to 15,000 feet) have a large lung capacity, on account of the

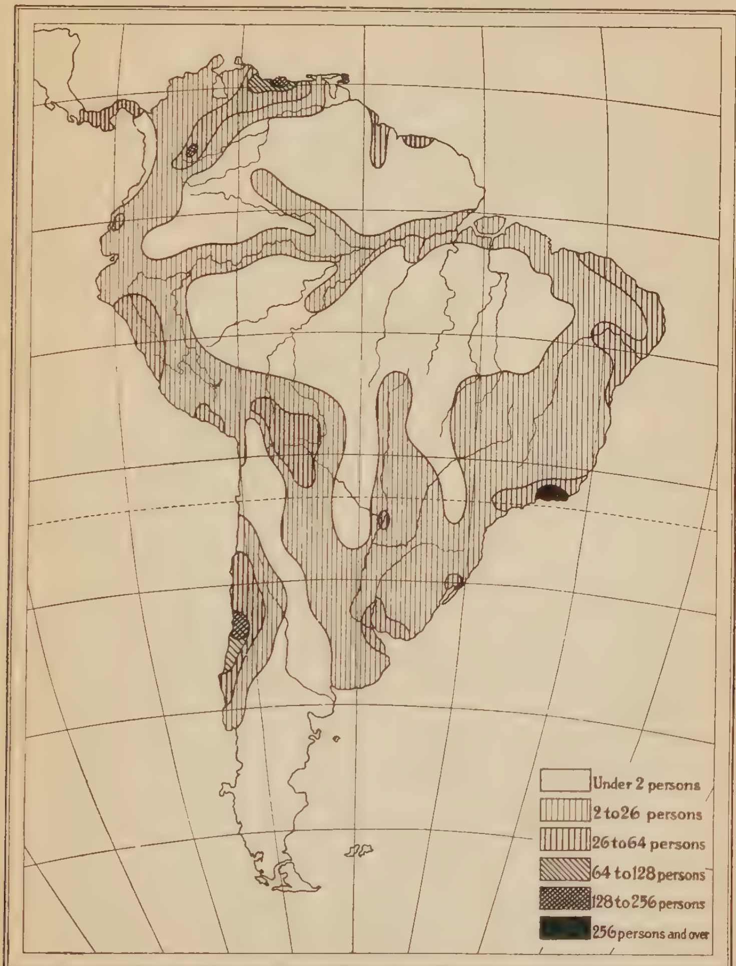


Fig. 56. Map showing density of population per square mile in South America. (Lyde.)

thin air. They are active and well on the highlands, but usually sicken if taken to low lands to live. On the other hand, natives of lowlands experience discomfort at high elevations. The ill effects of lessened pressure are rarely felt below 5,000 feet.

The Future of the Tropics

Because of their more comfortable temperature and more healthful conditions, the highlands of the tropics probably will be well developed earlier than the lowlands. At altitudes above 2,000 or 3,000 feet, tropical diseases, particularly malaria and yellow fever, are not prevalent. Civilized peoples can live comfortably at these altitudes, and where they have not already done so, they are likely to establish themselves in lands of moderate height where there is adequate water, and from them direct the development of the adjoining lowlands, the products and resources of which are of so much importance to the commercial world.

Questions

1. (1) If there were low land where the Gulf of Mexico and the Caribbean Sea are, what sort of climate would it have? (2) What effect would such a land area have on the climate of northern South America and Central America?

2. Why are not the highest temperatures found at the equator?

3. Explain the necessary relation of a place to the equatorial belt of calms, in order that it may have two rainy and two distinct dry seasons yearly.

4. Why is there no desert in tropical South America east of the Andes?

5. What changes would be produced in the climate of Australia if the main mountain range were on the west coast instead of near the east coast?

6. Which of the two important tributaries of the Nile (Plate VI) is the first to be in flood each year? Why? Which has the greater flood?

7. Suggest reasons which might delay the arrival of the Indian monsoon.

8. Explain the distribution of rainfall in Australia (Fig. 54).

9. What industries are likely to be connected with the distribution of population and rainfall shown in Figs. 54 and 55?

10. Account for the distribution of population in Brazil (Fig. 56).

11. Suggest ways in which the several types of climate found in the tropics might affect the character of imports from the outside world.

CHAPTER X

TYPES OF CLIMATE IN THE TEMPERATE (INTERMEDIATE) ZONES

Extent of temperate zones. The two temperate (or *intermediate*) zones lie on either side of the tropical zone. Defined by latitude, their equatorial limits are the parallels 23½° N. and S. respectively, and their poleward limits the polar circles, 66½° N. and S. There is, however, no marked change in climate as these boundary lines are crossed. The intermediate zones contain a little more than half (52.7 per cent) the area of the earth.

Southern hemisphere. The total land area of the south temperate zone is only about 4,000,000 square miles (Fig. 57), and its population not more than 20,000,000. In other words, the lands of the south temperate zone, taken together, have an area about one-third larger than that of the United States, and a population less than one-fourth as great.

About one-fourth of South America (1,800,000 square miles) and about the same proportion of its people (10,000,000) are south of the tropic of Capricorn. More than half of Australia and about three-fourths of its people (3,000,000) are in the same zone. Because of aridity this part of Australia is less important than the corresponding part of South America. New Zealand, but little more than 100,000 square miles in area, has a population of about a million. About 7 per cent of Africa lies south of the tropic of Capricorn. This area (700,000 to 800,000 square miles) has hardly more than 4 per cent of the people (5,000,000 to 6,000,000) of the continent.

The area of ocean in the south temperate zone is about twelve times as great as that of the land (Fig. 57). Hence much of this zone has a marine climate, which is much less variable than the climates of the north temperate zone.

Northern hemisphere. Nearly half of all land is in the north temperate zone, and the area of land there (26,000,000 square miles) is about equal to that of water (Fig. 58). In North America, all the

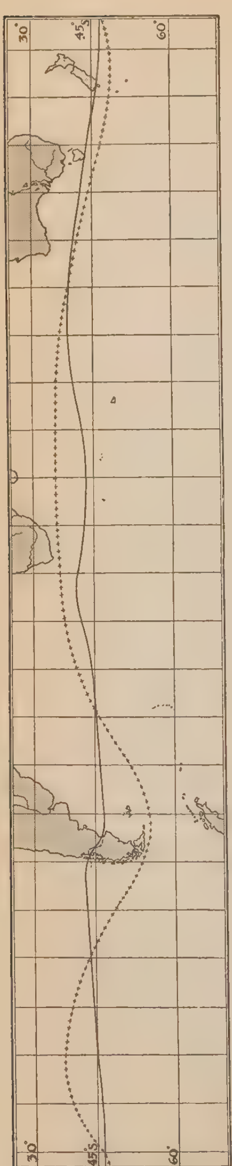


Fig. 57. Map of South Temperate Zone, showing land and water areas. Poleward limit of permanent habitations ++++++. Isotherm of 50° for warmest month——. Poleward limit of cereals, about latitude 45° in South America.

United States except northern Alaska, most of Canada, and part of Mexico, are in this zone. So also are nearly all of Europe, most of Asia, and part of northern Africa. This zone contains the greatest nations, and the majority of civilized people. Because of the greater expanse of land, continental climates are more prevalent than in the southern hemisphere. Only in certain broad aspects can the climates of the northern and southern intermediate zones be discussed together.

General Characteristics of Climates of the Temperate Zones

Variability. There are several types of climate in these zones, and their differences are perhaps as striking as their likenesses. Variability is the distinguishing feature of most of them. They vary in (1) temperature, (2) direction and velocity of wind, and (3) amount and distribution of rainfall. In general, the variability is less in the southern hemisphere than in the northern.

Sun influence. The fundamental cause of variability in these zones, as contrasted with the uniformity of tropical climates, is the great variation in (1) the altitude of the sun during the year, and (2) the length of day and of night. The sun never is overhead at any place in these zones, and during at least a part of the year it is many degrees from the zenith at noon (pp. 13-14). There are, accordingly, great differences in the amount of heat received at different times, and the year is divided into seasons which vary much in temperature.

Winds. The prevailing (westerly) winds of these zones are much less regular in direction and velocity than the trade-winds of the tropical zone, and are interrupted much by cyclonic storms, which vary greatly in frequency and strength.

Temperature ranges. The factors noted above lead to great variations of temperature from day to day, from season to season, and from place to place. The great and sudden variations of temperature make the term *temperate* singularly inappropriate for these zones. The weather at least is often most intemperate. In contrast with the conditions in the tropical zone (p. 99), observations through many years are necessary to get a correct idea of the climate. The yearly range of temperature in most places is far greater than the daily range.

In the same latitude, conditions vary widely from place to place, both with respect to variation of temperature and the time of greatest heat and cold. Inland, the highest and lowest temperatures of the year generally occur about a month behind the highest and lowest noon-altitudes of the sun, and the temperatures of the warmest and coldest months may be 50° apart, even in middle latitudes (as Chicago). Spring and autumn are much alike so far as temperature is concerned. Near the sea, the highest and lowest temperatures are about two months after the solstices, while spring is cold and autumn is warm. The maximum temperatures in summer in many cases exceed those of some tropical stations, and the lowest temperatures in winter approach polar cold. Summer weather is almost tropical,

Fig. 58. Map of North Temperate Zone, showing land and water areas. Poleward limit of cereals - - - - -. Poleward limit of permanent habitations + + + + + (in Greenland). Isotherm of 50° for warmest month ——.

and winter weather polar, in many parts of these zones. Weather and climate are therefore very unlike, so far as temperature is concerned. The average annual range, however, is as low as 20° in some places, even in comparatively high latitudes. Hence, in this zone, latitude is not a sure index of climate.

North temperate zone. The great expanses of land lead to marked contrasts in temperature between the two margins of this zone, within which some of the highest as well as some of the lowest known temperatures occur. The mean annual range varies from as little as 16° in southern California (San Diego, near the sea), to as much as 81° in northwestern Canada (Fort Chippewyan, far from the sea to windward).

Near the tropical margin of this zone, summers and winters are not extreme, and springs and autumns are long. Toward its poleward margin, on the other hand, the differences between summer and winter are great, and the transition seasons are short. Hence the length of the growing season for plants differs greatly in different parts of the zone, with important effects on life.

The variations of temperature are accompanied by variations in rainfall. In tropical lowlands, where temperatures always are high, it makes little difference to vegetation when rain comes; but where there are seasons of radically different temperatures, rain is useful to plants in summer, but not in winter. There are two general types of seasonal rainfall in the temperate zones, the *marine* or *winter type*, and the *continental* or *summer type*. In general, windward coasts and islands have the former, while interiors and leeward coasts have the latter.

Both the variations of temperature and the distribution of rainfall have far-reaching effects on life, some of which may be pointed out. Civilization, which apparently began near the tropics, has moved steadily outward (especially northward), until its chief centers are now in the middle latitudes of the northern hemisphere (p. 114), where the seasons are commonly regarded as responsible for much of the energy, thrift, and industry which have brought about this advanced development. The change of seasons stimulates effort. In summer, the conditions of life in many parts of the temperate zones are almost as easy as in tropical regions. Summer is a time of abundance, and winter a time of scarcity, in nature's supplies. In summer, it is necessary to provide food, clothing, and shelter for the winter, when nature does not provide. In order to live, therefore,

man must plan for the future, and to secure the things he needs requires regular effort; but with planning and effort, it is possible for him to secure what he needs. These conditions lead to mental, physical, and industrial development, and such development is the basis for advance in civilization.

South temperate zone. The limited extent of land in the south temperate zone gives it a climate far less variable than that of the corresponding northern zone.

Types of Climate

The north temperate zone is a patch-work of climatic types, whether the division is based on temperature or on rainfall. The south temperate zone, with its smaller land areas, mostly near the sea, has few important types of climate.

The chief types of climate of both hemispheres are determined by (1) the distribution of land and water, (2) winds, and (3) altitude. With insolation, these factors control both temperature and rainfall. The following important types of climate are recognized: (1) That of *windward coasts in low latitudes*, the *sub-tropical type;* (2) that of *windward coasts in high latitudes* (above 40°); (3) that of *continental interiors*, a type which varies much, especially in amount of rainfall; and finally, (4) the modifications, particularly of (3), brought about by altitude.

1. Windward coasts in low (below 40°) latitudes

General characteristics. The chief features of sub-tropical climates are moderate temperatures, with small annual and large diurnal ranges. In these respects the climate resembles that of the tropics. The rainfall is rather light in most places (Fig. 39), and is greatest in winter. The summers are dry. This climate is typically sunny, with a maximum of cloudiness in winter.

Distribution. The sub-tropical type of climate is found in latitudes affected alternately by the trade-winds, the tropical belts of high pressure, and the westerly winds. It is developed best on islands and on the western (windward) coasts of continents between the parallels of about 25° and 40°. It prevails over much of the land of the south temperate zone and is widespread about the Mediterranean Sea, extending from Spain on the west through Italy and the

southern part of the Balkan Peninsula into western Asia, as well as across the northern part of Africa. The wide extent of the sub-tropical climate about the Mediterranean has led to the name "Mediterranean climate." In North America, this type of climate is almost confined to the coastal part of California, south of San Francisco. The climate of southern California may be taken to illustrate the type.

Southern California

The southward migration of the wind systems in winter brings southern California under the influence of westerly winds. The northward migration of the wind systems in summer brings it in turn under the influence of (1) greatly weakened westerlies, (2) the tropical high pressure belt, and (3) the northern margin of the trade-winds.

Temperatures. The latitude is high enough to prevent a long continuation of temperatures as high as those of the tropics, and nearness to the sea prevents the seasonal extremes characteristic of most places in the temperate zones. Freezing temperatures are rare in low altitudes. Daily ranges of temperature are greater than yearly ranges. On the whole, the temperature of southern California is much like that of tropical lands at moderate altitudes.

In some ways the sub-tropical type of climate is the best in the world, and is described frequently as being like "perpetual spring." It is healthful, as shown by the popularity of southern California, where Pasadena, Riverside, San Diego, and other cities duplicate, on a small scale, the noted resorts in the Riviera of southern France and Italy. The sunny skies (68 per cent for San Diego) help greatly to make these places popular, especially in autumn, winter, and spring. The dry season (summer) may be disagreeable because of (1) the heat, (2) the drying up of vegetation, and (3) fogs and dust. Many places in California have least sunshine in the dry season on account of fogs.

The absolute lowest temperature at San Diego is 32°, and the absolute maximum 101°. Such variations are characteristic of tropical lands where the *average* annual range is not more than 15° to 20°. Interior stations show greater average ranges and more marked extremes, because they are farther from the sea. Their mean maxima are higher, their mean minima are lower, and the frequency of both high and low temperatures is much greater.

Rainfall. As in most similar localities (Fig. 39) the precipitation in southern California is rather low, and there is a marked winter maximum. The summers are almost rainless for a period which varies considerably from place to place. The interior valley of California is dry at all times because the coast ranges have taken the moisture out of the winds from the ocean. The dryness increases the range of temperature in the valley.

Rainfall and Crops

During the dry season, most vegetation dries up unless irrigated. Where water is available, the abundance of sunshine and the favorable temperatures lead to extensive irrigation, as in southern California and in the favored parts of southern Europe, western Asia, and northern Africa. Most of the crops of these latitudes, however, are grown during the rainy winter season and harvested in spring, before, or soon after, the beginning of the dry season. Winter crops are made possible by the temperatures of that season. Winter wheat is a common cereal crop, as in Italy, southwestern Australia, and California, while barley, resistant to both heat and dryness, was long the chief cereal in such climates. Corn cannot be grown without irrigation, for it needs a high temperature (such as that of the dry season) during growth.

The characteristic crop of the sub-tropical climate is fruit. Oranges, lemons, olives, grapes, and other fruits are produced abundantly in southern California and in Mediterranean lands. There is possibility of frost, however, and frost-fighting is an important part of the business of the California fruit grower. In many sub-tropical localities, fruit-drying is an important industry, favored by the dry, sunny weather which follows the ripening of the fruit.

2. WINDWARD COASTS IN LATITUDES ABOVE 40°; MARINE CLIMATE

Location. The marine type of climate in this zone is controlled by prevailing westerly winds, blowing almost constantly from ocean to land. The climate is cool, damp, and rainy. The change from the sub-tropical type of climate is gradual, and in some ways the two types are not very unlike.

In the western hemisphere, this type of climate is developed best (1) in Chile, south of latitude 40° and west of the Andes Mountains,

and (2) near the coast from San Francisco to the Arctic Circle. It is modified greatly even east of the low coast ranges.

In the eastern hemisphere, neither Africa nor Australia extends into latitudes high enough to have this type of climate; but it affects parts of Tasmania and most of New Zealand. It affects the coast of Europe from France to the Arctic Circle, and extends far inland because there is no continuous north and south mountain range to take the moisture from the westerly winds. The change from marine to continental conditions here is very gradual. From the British Isles, the annual rainfall decreases gradually eastward, the winter maximum gives way to spring and summer maxima, and the ranges and extremes of temperature become more marked. If the marine influence did not reach far inland, the densely populated and highly developed countries of western Europe, especially north of latitude 50°, would be far less important than now. The tempering effect of the westerly winds on the climate of western Europe is increased by the relatively high temperature of the central and eastern parts of the North Atlantic Ocean.

Temperatures. The variations of temperature are less than in the same latitudes elsewhere. Thus the yearly range of temperature at Sitka, Alaska, Lat. 57°, is only 25°, hardly more than that in some parts of the tropics, and at Thorshaven, in the Faroe Islands, Lat. 62°, the range is only 14.2°. In this respect, this type of climate resembles the sub-tropical type, though the actual temperatures are lower (Why?). It is the only really *temperate* climate of the intermediate zone.

Regions having a marine climate have mild winters and cool summers, and their average yearly temperatures are higher than those of other regions in the same latitude. For example, Ireland, which represents perhaps the extreme case, is 30° or 40° too warm for its latitude, 55° N.

Rainfall and humidity. Places freely exposed to westerly winds get much rain in winter, when the land is cooler than the sea. In summer, low lands are warmer than the ocean and receive little rain, though the dry season is much shorter than in lower latitudes (Why?). Mountainous western coasts have abundant rainfall, high humidity, and much cloudiness all the year. In some places fogs occur almost daily, and in extreme cases, as along the coast of Alaska, they may last for weeks at a time. Evaporation is extremely low.

Though the maximum precipitation is in winter, little of it is in the form of snow, except at high altitudes.

Effect on life. Cool summers, abundant moisture, and much cloudiness, prohibit the growth of many kinds of crops. For example, wheat and corn are not grown in the typical marine climate of western North America and northwestern Europe. Wheat requires a dry, sunny harvest season, and so its growth near the coasts in question is confined to places where topography modifies marine conditions, as in eastern Washington and eastern England. Corn needs a higher temperature and more sunshine than the marine climate affords. Oats, rye, and barley, however, are grown successfully in a cool, cloudy, damp climate. This is a chief reason why oats have furnished the staple food of Scotland. Various crops are grown near the northern limit of the intermediate zone in northwestern Europe and in Alaska. In Norway, rye, oats, barley, and potatoes are grown successfully within the Arctic Circle. In Alaska, barley, potatoes, cabbages, and turnips have been grown at Ft. Yukon, in latitude 66° 30′. The marine climate is also favorable for grass, which in some places grows ten or eleven months in the year. For this reason, the raising of live stock is or may be important in this climate. In the British Isles, for example, the grazing industry has long been the leading phase of agriculture. Mild temperatures and abundant moisture make Ireland always green (Emerald Isle), and the raising of cattle is a chief industry.

Marine climate also favors the growth of heavy forests. Good examples of such forests are found in northwestern United States (p. 370), where lumbering is an important industry and forest products are leading articles of trade. In the same region, mountains near the coast cause heavy precipitation, much of which is in the form of snow. The melting of the snow in summer keeps the streams full when the rainfall is least, and mountain streams afford water power (p. 290) for manufacturing. Among native tribes, forest conditions lead to hunting and fishing as regular pursuits.

The change of climatic conditions with increasing latitude has resulted in striking contrasts in man's activities. In the northern part of Chile, for example, there is a coastal desert at the margin of the trade-wind zone. Here conditions have favored the accumulation of guano and nitrate deposits, which have been the basis of important industries and commerce, and the cause of bitter strife between Chile and Peru. South of the desert, the sub-tropical type of climate has led to irrigation and the growth of fruits. Still farther south, where the climate is of the type under consideration, grazing and the raising of cereal crops and vegetables

are the chief occupations. In the extreme southern part, the heavy rainfall from the westerly winds supports luxuriant forests, and forest industries and fishing are the chief occupations. Similar contrasts exist along the western coast of North America from California northward, and along the coast of Europe from Spain to Norway.

3 CONTINENTAL CLIMATES

Regions affected. This type of climate, as its name implies, is found inland from windward coasts; but not at any fixed distance from the coast. We have seen already that the marine climate extends far from the western coast of Europe (p. 120), and but a very short distance from the west coast of the Americas (p. 119).

In the south temperate zone, the continental climate is found only in southern Argentina. North America and Eurasia, on the other hand, are broad in rather high latitudes (Fig. 58), and so have continental climates over wide areas. In North America, there is a sharp contrast between the marine climate of the western coast and the continental climate east of the westernmost high mountains, the continental climate affecting most of the United States and Canada. In Eurasia, because of conditions already noted (p. 120), the marine climate of western Europe grades into the continental climate which affects the Russian Empire and most of China.

Temperatures. The chief characteristic of the continental climate is *extremes of temperature*. These extremes are due largely to the fact that land absorbs and radiates heat much more readily than water does. The *winters* are cold, the cold increasing (1) with the latitude, and (2) with increasing distance from the sea to windward. In latitude 45°, in North America, the lowest temperatures are about −30°, and near the northern limit of the zone they reach −60° or even less. A great area in northeastern Asia, far from the ocean to windward, has extremely low temperatures in winter. In the United States, the temperature never falls to −40°, except in the extreme northern part and in high mountains, and there but rarely; but, except in the Gulf region, there is no large area east of the Pacific coast where temperatures 10° to 20° below freezing do not occur every year. The *summers* are hot. July averages of 60° are found even beyond the northern margin of the zone, and maximum temperatures of 80° to 90° are found close to the Arctic Circle. In the southern part of the zone, the summer temperatures are tropical.

The annual ranges of temperature are very great, especially in the northern part of the north temperate zone. In northwestern

Canada, the difference between the lowest and the highest temperatures of the year has been known to reach 150°, and in northeastern Asia, 180°. In the lower latitudes the extremes are not so great; the winters are milder, and the summers are not correspondingly warmer. In our southern states only small areas ever have temperatures above 100°, and in most parts of the zone the mean maximum temperatures are under 90°, or no higher than those occasionally recorded near the Arctic Circle.

Cyclonic influence. A second important feature of continental climate is the variability of weather from day to day. Cyclones and anticyclones interrupt the prevailing westerly winds frequently; hence there is repeated change from clear, cold, and dry days, to cloudy, warm, and damp ones. Because of the frequent storms, the winds may, in the course of a day or two, blow from all points of the compass, and each wind tends to bring its own distinctive weather conditions. The northerly winds of anticyclones in winter carry freezing temperatures almost to the southern margin of the zone. Southerly winds, on the other hand, carry warm air to comparatively high latitudes, and temporarily may produce a summer-like temperature in mid-winter, even as far north as New York and Chicago.

Rainfall. A third important element of continental climate is its rainfall, which is very variable, but as a rule either moderate or scanty (Figs. 39 and 59). In few places is it more than 40 inches a year, and most of it comes during the spring and summer. The fact that most rain falls when temperatures are favorable for plant growth is most important.

Eurasia illustrates the effect on rainfall of distance from the windward coast. The western slopes of the British Islands have 80 to 100 inches of rain yearly; Germany and western Russia have 20 to 30 inches; eastern Russia and western Siberia, between 15 and 20 inches; while large areas of central and eastern Siberia have less than 10 inches.

Arid and humid interiors. On the basis of rainfall, there are two principal subdivisions of continental climate, the one *humid*, and the other *arid*. These types merge into each other in a belt where the climate is *semi-arid*. Forests are characteristic of the humid climate, but they give place to grass lands where the climate is semi-arid, and to deserts where the rainfall is very slight. In a general way, moisture decreases with increasing distance from the ocean to windward; but topography and cyclonic storms modify this

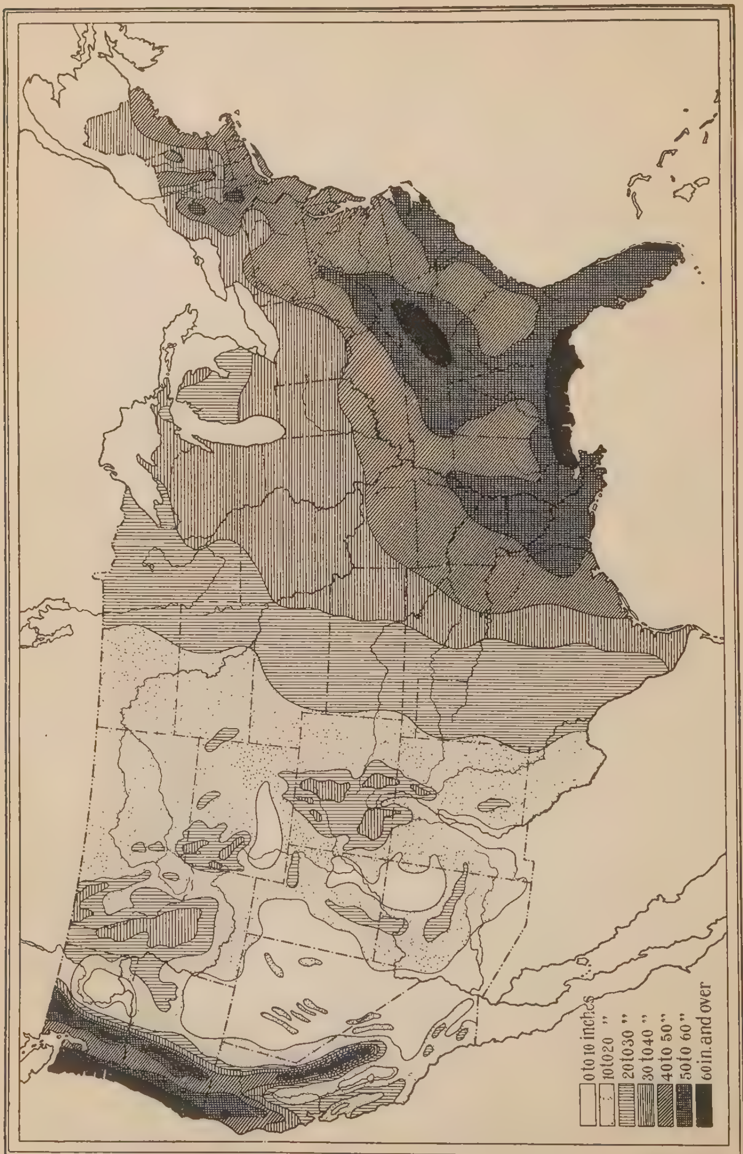


Fig. 59. Mean annual rainfall in the United States. (After Gannett, from data of U. S. Weather Bureau.)

general relation. Altitude also is an important factor in continental climate, especially in arid regions, because highlands increase precipitation. Lowland deserts may give place to grassy lands at moderate altitudes, and to forests still higher. As in tropical deserts, the effect of high elevations plays an important part in the life of the arid regions.

With but slight modification, the continental climates extend eastward to the oceans. Ranges of temperature are somewhat less near the eastern seaboard, and the rainfall is somewhat greater (Fig. 39).

Continental Climates in the United States

The interior of our country may be divided into (1) the *arid* region (Fig. 60), chiefly between the Sierra Nevada and Cascade mountains on the west and the Rocky Mountains on the east; (2)

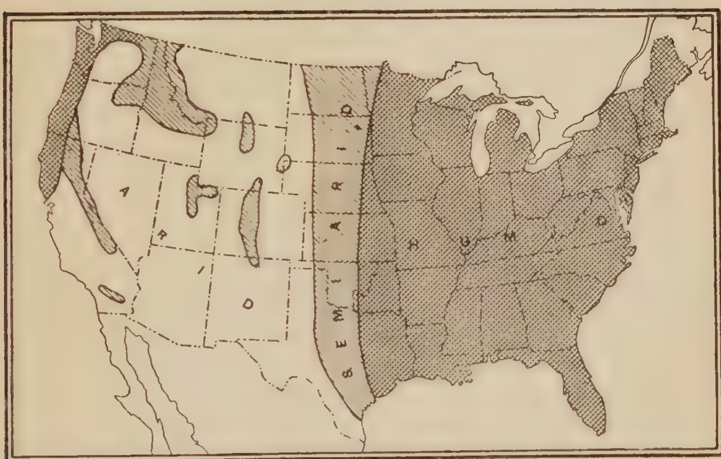


Fig. 60. Map showing arid, semi-arid, and humid regions of the United States. (After Newell.)

the *semi-arid* region between the Rocky Mountains and longitude 98° to 100°; and (3) the *humid* tract, lying farther east. All these regions have extremes of heat and cold. They also have great changes of temperature and humidity from day to day as a result of passing cyclones and anticyclones. The difference in the amount of rainfall, however, makes the conditions of life very different in the three regions.

(1) *The Arid Region*

The arid region (Fig. 60) includes most of the Cordilleran section of the United States, except the high mountains. Its western margin is near the western coast, because the mountains there stop much moisture which otherwise would be carried inland by the westerly winds. The average annual rainfall in the arid belt is less than 15 inches, and over large areas, less than 10 inches (Fig. 59). Sunshine prevails throughout the year, relative humidity is low, and evaporation high. The nights are usually cool even when the days are hot. The heat of summer is great, but the humidity is so low that the sensible temperatures are not very high. So far as comfort is concerned, the arid region has an agreeable temperature.

Effects of scanty rainfall. The scanty rainfall means scanty vegetation, except where high elevations cause rain enough to support grass or timber. The rapid evaporation of ground-water leaves the alkaline substances it contains in the soil, and the slight rains are not enough to dissolve and carry these away. In some places this gives rise to alkaline soils, unfavorable for vegetation. Where not alkaline, desert soils are naturally rich, because elements important for plant food have not been leached out or used up (p. 293). Hence where water can be applied to desert lands, they are highly productive in most cases.

Many mountains in the arid region receive much snow in winter, and this may afford water for irrigation. The total area which can be irrigated, however, is but a small portion of the entire arid tract (p. 293). Farming is therefore not the leading industry of arid lands. Where rainfall is enough to support even a meager growth of grasses, grazing is an important occupation.

Mining is important in parts of the arid West, though aridity has little or nothing to do with the development of ores. Desert conditions favor the accumulation of salt deposits, as about Salt Lake, and borax deposits, as in Death Valley, California.

The population of the arid section is necessarily scanty, because there is no natural basis for permanent or extensive settlement in most localities.

(2) *The Semi-Arid Region*

In the semi-arid region (Fig. 60), the yearly rainfall is between 15 and 20 inches (Fig. 59), most of which falls in spring and summer.

The tract is without high mountains, so that there is little increase of precipitation as the result of altitude, and forests are generally absent. The region is sunny, and the temperatures are high in summer and low in winter. The sensible effects of the extremes, however, are moderated by the dryness of the air. The open character of the country favors free circulation of the atmosphere, and fairly constant winds of moderate to high velocity are more or less typical of most of the region.

Effect on life. The semi-arid district is a region of grass land; there is not enough rain for most cultivated crops. Grazing consequently has been the most general occupation. Water is highly prized, and bitter contests have been waged over the question of its ownership. Thus the use of the waters of the Arkansas River, which flows from Colorado into Kansas, led to a long legal battle between the two states, because there was not water enough for both.

(3) *The Humid Region*

The semi-arid region merges gradually into the humid region farther east (Fig. 60). The temperatures of the two regions are not unlike, but in the humid region cloudiness and humidity are greater, and evaporation less; hence sensible temperatures are higher in summer and lower in winter. The precipitation rarely falls so low as 20 inches per year, and most of it comes in summer. The amount of rain necessary for crops without irrigation varies with the latitude. More is needed in Oklahoma than in Dakota, because the higher temperature and lower humidity of the former cause greater evaporation. In the western part of this region, trees grow in the river bottoms; farther east, they become more abundant, and forests are found (or were once) over large areas. Throughout the humid region there is rain enough for cultivated crops, and it contains some of the greatest agricultural tracts of the temperate zones.

Effects on life. The crops raised are determined largely by the climate. Wheat, for example, is raised most in the less rainy regions (Fig. 260), and its seed time and harvest are influenced by climate. In the north, spring wheat is grown, largely because the winters are too cold for wheat sown in the autumn. Farther south, where the winter season is shorter and milder, both winter and spring wheat may be grown, the former predominating in many sections. The harvesting of winter wheat begins in the south in June, and the harvesting of spring wheat ends in the north about the first of

September. The harder varieties of wheat, rich in gluten and good for macaroni, are grown in the drier sections (p. 360), while softer varieties, less rich in gluten, but good for flour, are grown where rain is more plentiful.

The best climate for wheat is one with a dry, sunny harvest season, such as that of the Sacramento Valley, California, and eastern Washington (p. 121). This ideal climate is not found in much of the humid interior, where wheat is the standard crop only in a north-south belt, some ten degrees in width, just east of the 100th meridian. Even here, the climate is not so good for wheat as that of eastern Washington.

East of the wheat belt, the heavier rains favor a variety of crops. Corn is the standard cereal in great areas (Fig. 259), though wheat, oats, and other crops are commonly grown in rotation with it. Corn is not grown so far north as wheat, because corn requires a higher temperature, and most varieties require a longer warm season. With corn, many other cereals, vegetables, and fruits are grown, requiring more moisture than wheat.

The humid continental region is the region of greatest development in the United States. It has the major part of the population (Fig. 281), it contains most of the chief cities (p. 399), its manufacturing and commercial activities are greatest (p. 383), and its transportation facilities are best (Fig. 279). All these things reflect the abundant yield of the soil, and this is a result, in large part, of favorable climate.

The abundance of rain and the topography of the eastern coast of the United States favor the development of swamps, and in low latitudes swamps invite diseases like those of equatorial regions (p. 103). The home of malaria in the United States is on the low plains and in the river valleys along the eastern coast south of New York. Yellow fever has been introduced many times into the Gulf and South Atlantic ports, but could not last from one summer to the next, on account of the frosts of winter.

Shore towns in nearly all latitudes feel the beneficial effects of the sea-breeze (p. 74), and many important seashore resorts from New Jersey northward are the result. In the higher latitudes, the ocean affects the temperature of coastal lands chiefly by lowering the temperature in summer, because of frequent winds (sea-breezes and cyclonic winds) from the east. The July mean for Labrador, for example, is 13° or 14° lower than that for Norway House, at the

northern end of Lake Winnipeg, near the great Canadian wheat district. In Labrador none of the cereals will ripen. The sparse population there finds its chief support in fishing, hunting, and trapping. Fishing especially is important during the summer, and when the catch is small, the people suffer greatly from want during the long, cold winter.

The same factors which lower the temperature and increase the rainfall along our eastern coast increase cloudiness and fog. Places exposed freely to the sea (like Newfoundland) have conditions of humidity, cloudiness, and fog similar to those of marine climates on western coasts. Along the eastern coast, therefore, the continental climate is somewhat modified.

The humid parts of the north temperate zone are the greatest cereal districts of the world. They bear the same relation to the cultivation of cereals that the semi-arid steppe lands, with their grassy vegetation, hold to the live stock industry of the world. Thus the great wheat regions lie mainly between the 40th and 55th parallels. Rye, closely related to wheat in its uses and conditions of growth, replaces wheat in many places where the soils are too poor for the latter. Of the other great cereal crops in this belt, oats and barley are grown more to the north, and corn to the south. Hence, through the heart of the temperate zone is found the home of all the cereals, save rice, which serve as food for man. This arrangement of important crops influences both the distribution of population and the movement of commerce. The populous part of the temperate zone corresponds closely to the cereal belt. Much of the commerce of the world now moves along east and west routes in these same latitudes. No other country is situated so well as the United States with respect to cereal growing lands.

The whole humid section in the interior of this country is exposed to sudden frost in late spring and early autumn (Fig. 61), and in either case widespread damage may result. Its southwestern part is exposed to hot winds from the south which, in exceptional cases, wither and kill crops. Droughts are common, though less frequent and less widespread than in monsoon countries. Almost every year some part of the humid portion of the United States suffers from too little rain; but severe drought rarely affects a great area, or the same area frequently. In monsoon countries like India, on the other hand, a large area suffers from drought at the same time, and the same area may suffer for a period of years. Tropical and sub-

tropical Australia also has frequent and long-continued droughts which affect large areas. In spite of its extremes of climate, central and eastern United States is a highly favored agricultural region, largely because of its reliable rainfall.

Near the northern limit of the north temperate zone the summers of interior lands are too short and too cold for cereals. Even in the most favored parts of continental interiors, the hardiest cereals cannot

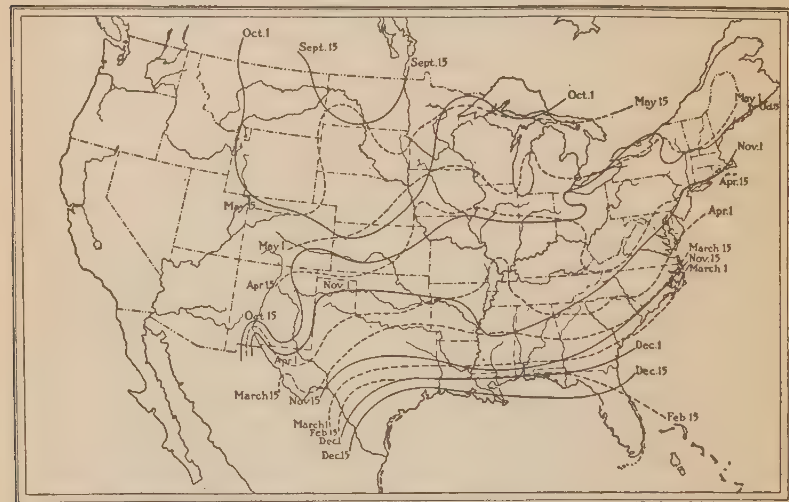


Fig. 61. Map of United States showing average dates of last killing frost in spring (broken lines) and first killing frost in autumn (solid lines). (After U. S. Weather Bureau.)

be grown much beyond the 60th parallel (Fig. 58). Dense forests disappear in most places before the margin of the zone is reached, being replaced by the scattered trees and scanty vegetation which mark the beginning of the frozen, polar wastes. Both Canada and Russia have large areas of this nearly worthless, almost uninhabited territory (p. 336). The United States, on the other hand, is neither too far north nor too near the equator. Climatically, it has the best position of any large country.

4. MOUNTAIN CLIMATES

Temperature. Even moderate altitudes so affect temperature as to determine what crops may be cultivated. For example, in

the plateau sections of Pennsylvania, in latitude 40° to 42°, corn cannot be depended on to ripen at an altitude of 2,000 feet. In some of the drier, hence warmer (in summer) and sunnier, parts of the arid West, corn, under irrigation, will ripen at much higher altitudes (4,000 feet about Great Salt Lake). In general, the upper limit for even the hardiest crops does not exceed 6,000 feet, even in the lower latitudes of the temperate zone. In contrast, corn is grown in Bolivia at an altitude of 10,000 feet, and wheat even higher. The *timber-line* (upper limit of timber) in the United States ranges from an altitude of about 11,000 feet at the south, to 7,000 or 8,000 at the north, and the level at which snow lies most of the time is not far above these limits. Hence, so far as agriculture is concerned, the higher lands of the temperate zone are of little use.

Precipitation. The effect of altitude on rainfall is the same in the temperate zone as elsewhere. It increases the amount of precipitation, and tends in many cases toward a maximum in winter. The increased precipitation at higher altitudes usually results in heavy snowfall in winter. Thus Baltimore, altitude 104 feet, has an average of 23.8 inches of snow annually, while Grantsville, Md., altitude 3,400 feet, has 71.2 inches. Summit, the top of the pass (7,017 feet) crossed by the Southern Pacific railroad east of Sacramento, Cal., has an average snowfall of 433 inches a year, and twice in thirty-three years the amount has reached 775 inches. Sacramento, on low land to the west, has only a trace of snow each year.

Winter snowfall is an important factor in the flow of many rivers. Disastrous winter and spring floods are the result in some cases (p. 76), and in others the supply of water from melting snow is an important aid in (1) the development of water power, (2) the maintenance of a sufficient depth of water for navigation, and (3) irrigation. Heavy winter snows and snowslides offer serious problems to railroad lines which run at high levels, and at the bases of mountains. Snowslides are one of the things to be feared about mines in mountains, and mountain villages have been destroyed by them.

Mountain conditions of temperature and rainfall favor forests, and make many mountains the sites of lumbering (p. 316). Forest trees thrive far above the altitudes which limit crops. Even in arid regions, some areas 5,000 to 6,000 feet high have rain enough to support forests of commercial value.

Many mountains serve as health and pleasure resorts (p. 317). Most mountain health resorts are visited chiefly by persons afflicted

with diseases of the lungs, especially tuberculosis. Mountain climate is not a cure for this disease; but the conditions in the mountains may aid in checking it, or may even enable the organs affected to throw it off. The favorable conditions are (1) the pure, dry air characteristic of the higher altitudes of many mountains, and (2) the decreased density of the atmosphere, which stimulates the lungs to greater activity. In the arid parts of western United States, these conditions are associated with bright, sunny weather, which favors out-of-door life.

Questions

1. Explain the absence of summer rainfall in sub-tropical climates, even with winds from the ocean.

2. Account for the morning fogs of the coast of southern California in summer.

3. Why is the Pacific Ocean not the chief source of moisture for the United States?

4. Explain the differences in climatic conditions at different points on the 41st parallel in the United States. Along the 32nd parallel.

5. Explain the increase in rainfall from San Diego northward to Astoria. (See Fig. 59 and Plate II.)

6. Why are the limits of cereals and of permanent habitations nearer the equator in Fig. 57 than in Fig. 58?

7. How does the isotherm of 50° in Fig. 57 differ from that of Fig. 58? Why?

8. Why do the lines showing average dates of frost (Fig. 61) turn northward over Lake Erie and along the south Atlantic coast?

9. Why is the snowfall in the Mississippi Valley heavier than that in the corresponding latitudes on the Atlantic coast?

10. Suggest reasons, based on climate, why there is little commerce between lands of the south temperate zone.

CHAPTER XI

CLIMATE OF POLAR REGIONS

General Considerations

Extent of polar regions. The limits of the polar regions are commonly placed at the Arctic and Antarctic circles; but they are sometimes regarded as being limited equatorward by the isotherm of 50° for the warmest month, an isotherm which marks the approximate limit of the growth of trees and cereals (Fig. 62). In this discussion, the latitude division is used. Thus defined, the polar regions have an area about one-twelfth that of the earth.

General features of polar climate. All polar regions are alike in having the sun above the horizon for more than twenty-four consecutive hours, and below the horizon for a similar period, once each year. Near the margins of these zones, the longest period of continuous sun is only a few days (of 24 hours each); but the time during which the sun does not set increases poleward, and at the poles the day (period of continuous light) is six months long (p. 43). During the period of continuous light, insolation is greater in polar regions than in low latitudes (p. 35), but the temperature of the lower air is not raised accordingly, because (1) the sun's rays are very oblique (Fig. 21), and (2) much of the heat which reaches the surface melts ice and snow, and is not effective in warming the air. The result is a low temperature for the year, and, except for lands free from snow and ice, a low temperature at all times of the year.

Temperature. Many of the recorded temperatures of January in the Arctic region range from — 40° to — 60°, while the warmest month has an average temperature of 32° or more in many places. The maximum summer temperatures close to the margin of the zone are locally as high as 80°, or even 90°; but such temperatures occur only where there are large areas of land free from snow and ice. Most of the Antarctic region has a summer temperature below the freezing point even during the warmest month, so far as present records show.

The annual range of temperature in the Arctic region is greater

than that in the Antarctic, because more land in the former is without snow and ice in summer. Verhoyansk, in Siberia, just within the Arctic Circle (Lat. 67° 6′), has a July mean of +60° and a January

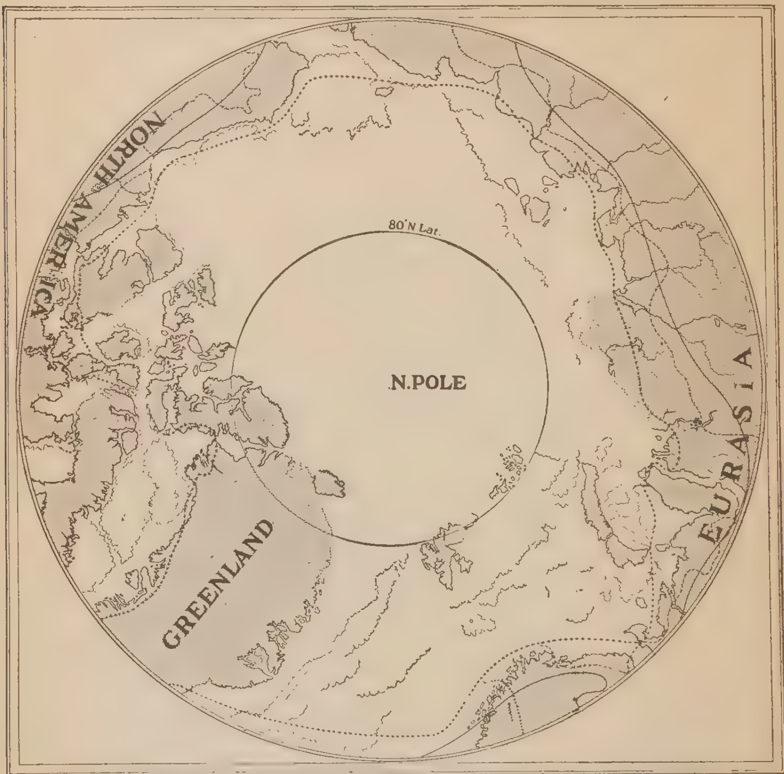


Fig. 62. Map of North Polar Zone, showing land and water areas. Poleward limit of growth of cereals......Poleward limit of growth of forest trees - - - - -. Poleward limit of permanent habitations + + + + +. Isotherm of 50° for warmest month ———.

mean of —60°. In contrast, Hammerfest (Lat. 70° 40′), on the coast of Norway, and the most northerly town in Europe, has a January mean of 23°, and a July mean of 53°. Hammerfest shows the full effect of the ocean on the temperature of windward coasts in high latitudes.

Humidity and precipitation. The low temperatures affect the other elements of climate. They mean little evaporation, and hence little moisture in the air. The relative humidity varies from extremely low, especially far from the sea to windward, to relatively high, particularly on windward coasts. The precipitation is light, probably averaging less than 15 inches a year except on windward coasts.

The Shackleton expedition to Antarctica found, from recording instruments left by a preceding expedition, that the average precipitation for six years had been the equivalent of 7 to 8 inches of rain. Most of the precipitation in polar regions is in the form of snow, and is frequently accompanied by violent winds. Rain is said to fall in most parts of the north polar region during the warmer months. In the south polar region the Shackleton expedition found all precipitation during 13 months to be in the form of snow.

The great fields of snow and ice in the polar regions are not due to heavy snowfall, but to the preservation of most of that which falls.

In summer, fogs are common, and are a great hindrance to navigators.

The Antarctic Region

The Antarctic region is largely ice-covered water and ice-covered land. The scattered land areas which have been discovered are probably parts of an Antarctic continent. Beyond the edge of this ice-covered land the surface rises toward the interior to heights of several thousand feet.

If the south polar region were limited by the isotherm of 50° for the warmest month, it would include everything south of the 55th parallel.

Temperature. The great expanses of ice and ice-water do not allow the temperature of this zone to rise much above 32°, even in summer. During this season, fog and cloud are so frequent that much insolation is cut off. Fogs and clouds are therefore important factors in keeping the summer temperatures low.

The mid-winter (July) temperatures of the lower latitudes of this zone are about —15° to —20°, so far as recorded. The temperatures of higher latitudes are probably much lower. The seasons between winter and summer are very short. The one shows a rapid rise from the low temperatures of winter, and the other a rapid drop from the temperatures of summer.

Effects on life. The Antarctic region is without most kinds of vegetation familiar to us. Some mosses and lichens are found on such

lands as are free from ice for a part of the year, but no form of vegetation useful to man is known. The animal life is mainly marine, whales and seals being characteristic. The waters abound in lower forms of life, such as molluscs and still simpler types. On land, animal life is represented by a few species of birds and insects. Great rookeries of penguins form one of the most remarkable assemblages of bird life to be found anywhere. The albatross, gull, and some other kinds of sea-coast birds also are found. From the standpoint of life in general, however, the Antarctic lands are as close an approach as there is to an absolute desert.

The Arctic Regions

In the higher latitudes the Arctic Ocean is covered with ice most of the year, though the ice is more or less broken in summer. In the lower latitudes much of the ocean is free from ice all or part of the time. Snow and ice cover all but the fringe of Greenland, and the larger part of many other islands. The Arctic portions of the continents are not covered by ice and snow during the summer, and their climate is in sharp contrast (How?) with that of regions which are so covered. There is also a great contrast between the interior lands which are snow-free during the summer, and windward coasts, such as western Alaska and northwestern Norway, which are affected by the moderating influence of winds from the oceans (p. 134).

Temperature. The temperatures of this zone vary widely. The lowest yearly temperatures are found where there is a permanent covering of ice. Such observations as are recorded indicate a January mean of about $-40°$ for northern Greenland, while its July mean is near the melting point. The continental interior of Siberia is even colder than Greenland in winter. In summer, however, this same region, being without snow or ice, becomes very much warmer than Greenland.

Arctic lands free from snow in summer have great extremes of temperature, and summer maxima of 60° to 80° are almost typical of the margin of the zone. Temperatures of 90° or more are reported frequently from Alaska and Siberia. An extreme range of 150° for the year is common, and the highest summer and lowest winter temperatures recorded are more than 180° apart.

The extreme and long-continued cold of winter is sufficient to freeze the water in the ground to the depth of scores of feet, and the temperatures of summer suffice to melt the ice in the top part only of the soil.

Plant life. The relatively high temperatures which prevail on ice-free land in summer permit the growth of many kinds of plants. As compared with the temperate zone, however, the amount and variety of vegetation are meager. Stunted trees of the hardier types, such as larches, pines, birches, and willows, grow near the border of the Arctic zone (Fig. 62). The northern limit of these trees is near the 70th parallel in Siberia and northwestern Canada. Dwarf willows and birches (hardly trees) are said to occur 8° or 10° farther north. Mosses, lichens, and other low types of plants abound in the Arctic tundra, which becomes a sea of mud as it thaws out during the summer. In the dry places in the tundra, and on southerly slopes where drainage of the soil is good and where insolation is great, there are many flowering plants, some of which produce berries. On the west coast of Greenland, poppies grow north at least to latitude 78°. The plants of these high latitudes are rapid growers, as the short growing season would let no other plants mature.

The temperatures of air and soil exclude crops from nearly all the polar region. There are a few localities, as in northern Norway and favored spots in Alaska and Siberia, where hardy cereals and some vegetables may be grown (Fig. 62).

Animal life. Animals, as well as plants, are more abundant in the Arctic regions than in the Antarctic. Sea life is more abundant than land life. The larger sea animals are similar to those of the Antarctic, and include whales, seals, and walruses. All these animals are important to the people living in the Arctic region, and are the basis for certain industries carried on from places in lower latitudes. Thus, sealing and whale fishing are carried on close to the Arctic Circle, and even within it. The Arctic seas also teem with smaller forms of life, such as molluscs and small crustaceans. Birds are prominent in the summer. The little auk, dovekies, guillemots, and (locally) the eider duck abound. Among land mammals, the reindeer, fox, hare, polar bear, and musk-ox may be mentioned.

Arctic people. The Arctic region, unlike the Antarctic, is inhabited by human beings, the best known of whom are the Eskimos (Fig. 62). The population, however, is scanty, scattered, and, on the whole, not highly civilized. Along the southern margin of the zone, there are many small groups of people. Farther north, the groups are fewer and smaller, and more confined to coasts. The most northerly permanent settlements are on the west coast of Greenland, the northernmost, Etah, being above the 78th parallel.

For all inhabitants of polar regions, life is a constant struggle. The cold means poverty of resources, a constant fight for food and clothing, and consequent inability to progress. Edible plants are absent, except in the lower latitudes of the zone, and for a short time each year. Land animals, like the reindeer, are comparatively scarce on account of the meager vegetation. Hence the people depend in large part on marine life, and most of them live along the coasts.

Meat is the principal food, and is furnished by the seal, the walrus, and fish, supplemented by the reindeer, the hare, the bear, and birds. Most of this food can be obtained only during the time of light, which is therefore the hunting season. Food for winter is preserved easily because of the cold. Since fuel and means of cooking are meager, much meat is eaten raw. In north Greenland, the tiny fire — a little oil with a wisp of grass or moss for a wick — is used chiefly for melting snow and ice for drinking water. The dependence of the people on animal life makes them hunters and fishers. The hunters are partly nomadic, going about in search of game during the summer, but having fixed habitations for winter.

Most of the Eskimo's clothing is of fur. Plant fibers which could be woven or braided together are unknown, except as they are brought in from other lands. The materials used in making dwellings depend on local circumstances. Where forests are accessible, as along the margin of the zone, or where driftwood can be had from the ocean, as along some coasts, wood is used. Elsewhere, the winter house is usually of stone or snow. During the hunting season, the hunters live in tents of skins.

Weapons and utensils may be made from wood, if it is available; more commonly they are made from bone and hides. The use of these animal products is the characteristic feature of the arts and crafts of the Eskimos. Perhaps in no other thing is their skill shown better than in the making of their kayaks (boats), where the only materials to be had are bone, pieces of driftwood, and hides. Out of these they fashion a craft wonderfully adapted to the uses to which it is put.

Looked at with reference to their surroundings, the Eskimos hardly can be regarded as backward. Probably they make better use of the things at their command than more highly civilized men could, but Arctic climate is too great a handicap to allow them to progress far.

Questions

1. Why is rainfall relatively unimportant in affecting the distribution of people in the polar regions?

2. If the entrance from the Pacific to the Arctic Ocean were widened greatly, what would be the probable effect on the climate of polar North America?

3. Suggest reasons why the Antarctic has been less well explored than the Arctic regions.

4. Why do trees grow in higher latitudes in Asia than in North America (Fig. 62)?

5. What factors determine the course of the isotherm of 50° in Fig. 62?

6. Why is there an ice-cap over central Greenland and not over lands in the same latitude in northern Asia?

CHAPTER XII

THE OCEANS

General Considerations

Importance of the oceans. The oceans are of great importance to the rest of the earth in many ways. Their effects on temperature and atmospheric moisture have been noted (pp. 51, 57). The waves of all seas are constantly wearing away the land in some places, and

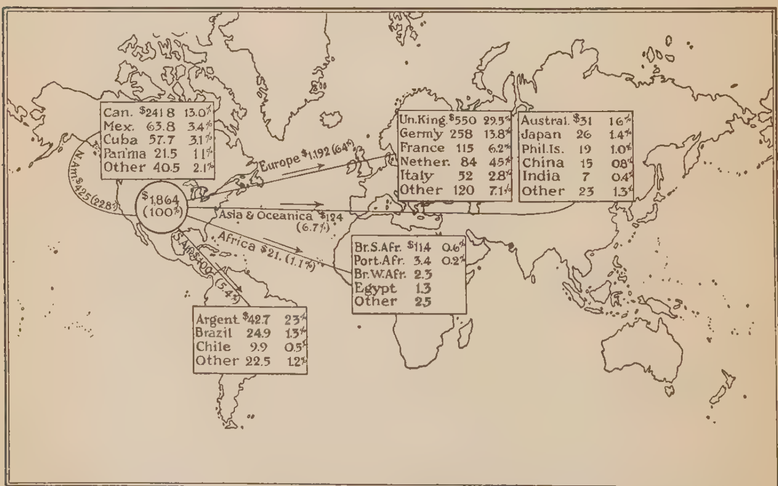


Fig. 63. Diagram showing destinations of exports from the United States by continents and leading countries (1910). (Values in millions of dollars; percentages are proportions of total exports.)

building new land elsewhere. On the whole, destruction exceeds building, so far as land is concerned; consequently, the ocean tends to increase its area at the expense of the land (p. 348).

The oceans are an important source of food, and furnish large amounts of other useful materials. Thousands of people are em-

ployed in getting commercial products from them. Other thousands are engaged in the carrying trade on the seas. Formerly the oceans were barriers to travel and communication, but swift steamships and cable lines now make communication between the continents easy. The voyage across the Atlantic formerly took as many weeks as it now takes days, while the happenings of this morning in Europe may be printed in the evening papers of Buenos Aires. Nine-tenths of our foreign trade is carried by vessels. Enormous quantities of goods are shipped annually to the United States from all the leading countries of the world, and from the United States to these countries (Figs. 63 and 64), over the ocean highway.

Distribution and area. The oceans encircle the earth in latitude 60° S. (Fig. 57), and the waters south of 40° S. are sometimes called

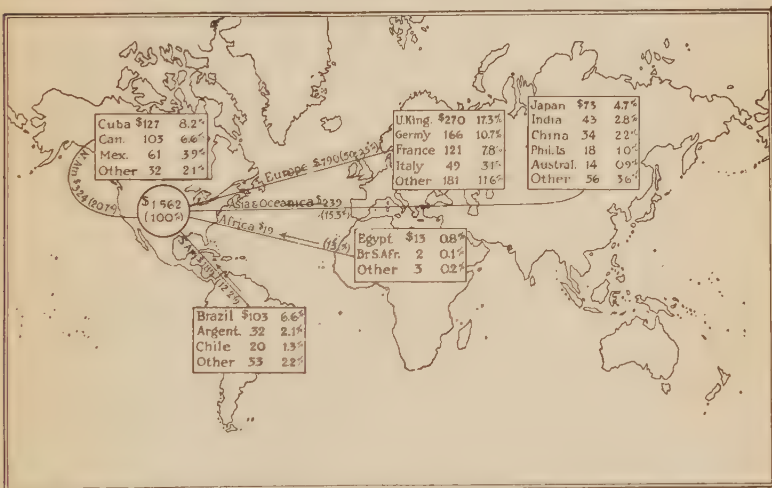


Fig. 64. Diagram showing sources of imports to the United States by continents and leading countries (1910). (Values in millions of dollars; percentages are proportions of total imports.)

the Southern Ocean. From it the Atlantic, Pacific, and Indian oceans extend northward thousands of miles. In the northern hemisphere the land makes an almost complete circuit in latitude 60° to 70° (Fig. 58), whence it extends southward in two great arms. North of latitude about 70° lies the Arctic Ocean, almost surrounded by land

(Fig. 62) and therefore with but narrow connections with the larger oceans. The area of the different oceans is about as follows:

Arctic Ocean	5,200,000 square miles
Indian Ocean	28,000,000 square miles
Atlantic Ocean	35,000,000 square miles
Pacific Ocean	67,000,000 square miles
Southern Ocean	5,700,000 square miles

Exploration of the ocean. The motions of the surface waters, such as waves and tides, may be studied from the shore, but it has taken the work of many exploring expeditions to give us our present knowledge of the depths of the ocean.

The depth of the ocean is known by soundings, which are made from ships by reeling out a heavy weight held by a fine steel wire. A sounding of 3,000 fathoms (a fathom = 6 feet) can be made in about an hour. A series of soundings in any region give a fairly accurate idea of the form of that part of the sea-floor.

Small samples of sediment from the bottom of the sea are brought to the surface by various sorts of apparatus. Larger samples of material from the bottom and specimens of deep-sea life are obtained by dredges. Another device, known as a *water-bottle*, is used to secure samples of water from various depths, while a self-registering thermometer records the temperatures at different levels.

Materials of the bottom. Most of the sea-bottom is covered with soft sediment. Some of it was carried to the sea by rivers, some was worn from the shores by waves, some was blown from the land, some is made up of the shells and skeletons of organisms which lived in the water, and some consists of fine debris thrown out from volcanoes beneath the sea. A little cosmic ("shooting-star") dust is also present. Near many shores, gravel and sand from the land cover the bottom. Beyond the gravel and sand, fine sediments, such as mud and clay, prevail; but sediments of organic origin are found in many places. Thus coral reefs and mud made by the grinding up of coral by waves are found in shallow water in many places in low latitudes.

Ooze is the name applied to those soft materials of the sea-bottom composed largely of the shells and other hard secretions of tiny organisms which live in the water. Many of them live near the surface, and their shells sink when the organisms die. The various oozes are named from the animals and plants which contribute most to them.

Below the depth of about 2,200 fathoms, the ocean-bottom is covered with *red clay*, the particles of which came from many sources.

Most of it consists of the decomposed products of (1) materials thrown out from volcanoes, (2) dust blown from the land, (3) shells and other hard parts of marine life, and (4) meteors.

Depth and pressure. The average depth of the ocean is about two and one-half miles, or nearly 13,000 feet. The depth exceeds four miles in many places, and the area of very deep water is much greater than that of very high land. The areas which are far below the average depth of the ocean are known as *deeps*. The greatest depth of water known, 32,078 feet, is in the Pacific Ocean, near the Philippine Islands. This depth is more than the height of the highest mountain (Mt. Everest, 29,002 feet) above the sea. There are other areas exceeding five miles in depth in the Pacific, which is the deepest ocean. The greatest depth of water known in the Atlantic is Blake Deep (27,366 feet), north of Porto Rico. In few other places in the Atlantic does the depth reach 20,000 feet. The Indian Ocean is not known to have depths much exceeding 20,000 feet, and the deepest known places in the Arctic and Antarctic seas are still less.

The pressure at the bottom of the oceans is very great. At a depth of one mile, it is about a ton to the square inch, while in the greatest depths it is six tons. This pressure would crush some kinds of stone. Yet the ocean water does not become much denser (is not compressed much) even under so great pressure. Objects such as pebbles, which sink readily at the surface, sink readily to the bottom.

Topography of the bottom. The surface of the land is made rough in various ways, especially by running water and winds; but most of the sea-bottom is nearly flat. In spite of its general flatness the sea-bottom has many irregularities, for there are (1) *volcanic cones*, some of them built up from the bottom of the deep sea to elevations far above its surface (p. 194); (2) *steep slopes*, such as those (a) between the continental platforms and the deep-sea basins and (b) about some of the deeps; (3) *valley-like depressions*, especially on the continental shelves; (4) *great ridges* somewhat like the mountain ridges of the land; and (5) *broad, plateau-like swells*. Submarine slopes as great as 1 mile in 8 are rare, and 1 mile in 20 not very common. The latter would make a steep railway grade.

Volcanic cones are most numerous in the Pacific Ocean. Many of the valley-like depressions on the continental shelves are continuations of valleys on land. Thus the Hudson, Delaware, Susquehanna, St. Lawrence, and other valleys are continued out under the sea. Such submerged valleys are thought to have been

formed by rivers when the areas where they occur were land. Examples of mountain-like swells are furnished by Cuba and the adjacent islands, which are really the crests of a great mountain system rising from deep water.

Composition of sea-water. One hundred pounds of average sea-water contain nearly three and one-half pounds of dissolved mineral matter. More than three-fourths (nearly 78 per cent) of this is common salt, but nearly all other substances found in the earth's crust are present, most of them in very small quantities. If all the salts dissolved in the sea were taken out of solution and laid down as solid matter on the ocean-bottom, they would make a layer about 175 feet thick. In the past, the evaporation of water from salt lakes, perhaps cut off from the sea by changes of level, has formed important salt-beds. New York has a valuable salt industry near Syracuse, depending on such deposits of rock salt (p. 183).

The mineral matter in sea-water makes it a little heavier than fresh water, and makes it freeze less readily. Its lower freezing point (26°–28° F.) often leaves the ocean free from ice when nearby bodies of fresh water are frozen over.

Sources of mineral matter. Dissolved mineral matter is being carried to the sea by rivers all the time, and they have brought the sea most of its mineral matter, though some of it may have been dissolved from rocks beneath the sea, or about its shores. The mineral matter carried in solution to the sea by rivers in a year would make nearly half a cubic mile of solid matter. Those minerals of the land which are dissolved most easily get into rivers, and thence to the sea, in greater quantity than those which are less soluble.

Withdrawal of mineral matter from the sea. Of the mineral matter carried in solution to the sea, calcium carbonate, of which most shells are made, is most important to ocean life. The amount of this substance dissolved in river-water is nearly as great as that of all others. The amount of common salt in river-water is too small to be tasted; yet the amount of it in sea-water is more than 200 times that of calcium carbonate. The reason is that calcium carbonate is taken out of the water all the time by animals, to make shells, coral, etc., while most of the salt carried to the sea stays in the water; and this probably has been true for millions of years.

Gases in sea-water. Sea-water also contains dissolved gases, the most abundant being nitrogen, oxygen, and carbon dioxide. The amount of oxygen dissolved in the ocean is more than 1/300 of that in the air; the amount of nitrogen about 1/100 that of the air,

while the amount of carbon dioxide in the sea is 18 times that in the air. Much of the gas in the ocean was dissolved from the atmosphere.

The oxygen of the water is being used all the time by sea animals, and its supply is being renewed all the time by solution from the air. Animals and plants do not use the nitrogen dissolved in sea-water, and the same nitrogen probably stays there from age to age. The carbon dioxide is being used all the time by the plants of the sea, and some of it is constantly escaping into the air.

Salinity, density, and movement. For several reasons, some parts of the sea are more salty than others. (1) The salt is left behind when ocean-water evaporates. Since evaporation is more rapid in some places than in others, the water becomes more salty where evaporation is great, as in some hot climates. (2) Where much rain falls, and (3) where large rivers enter, the sea-water is freshened. In these ways the saltness of the sea-water at the top of the ocean is changed all the time.

Every change in the saltness of sea-water changes its density, and unequal density causes movement. When surface water becomes denser than that beneath, it sinks, and lighter water comes in over it from all sides. When the surface water of one place becomes less dense (fresher) than that about it, the lighter water spreads out on the surface, as oil spreads on water. Since variations in saltness are being produced all the time, motion due to unequal density is constant. Movements brought about in this way are usually very slow.

Temperature of the Sea

Temperature of the surface. The surface of the ocean, like that of the land, is warmer near the equator and cooler toward the poles (Fig. 65). Near the equator its temperature is about 80° F.; near the poles, where not frozen, it is 26°–28° F. When frozen, the surface of the ice may become as cold as the air above it; but the temperature of the water just beneath the ice is 26°–28° F. The decrease of temperature toward the poles is by no means regular, as shown by the isothermal chart (Fig. 65).

In the open sea, ocean currents help to make the isotherms depart from the parallels (p. 51). Some currents are *cold*, flowing into warmer water, and some are *warm*, flowing into cooler water.

Rivers help to make surface temperatures unequal, for many of them are warmer than the sea in summer, and colder in winter. Partly enclosed arms of the sea in low latitudes are warmer than the open ocean in the same latitude.

Temperature and movement. Water expands slightly when warmed. Warm water is therefore lighter than cold water, if both are equally salt. It follows that unequal surface temperatures cause movement of the surface waters, and since the surface temperature is kept unequal all the time by unequal heating, by inflow of rivers,

Fig. 65. Map showing mean annual temperatures for the surface waters of the oceans. (After Lyde.)

and by melting ice, there is constant though slow movement of the surface waters.

Temperature beneath the surface. Sea-water becomes cooler with increasing depth, except where the surface is at or near the freezing point. Even where the surface water is warmest, the temperature at a depth of a few hundred fathoms is below 40° F.

It is estimated that not more than one-fifth of the water of the ocean has a temperature as high as 40° F., while its average temperature is probably below 39° F. Only in certain areas of shallow water, and in the partly enclosed seas of relatively low latitudes, is the temperature of the water at the bottom as high as 40°.

Movements of Sea-Water

Causes

We have seen that differences in saltness and in temperature make waters unequal in density, and so produce a slow circulation of the waters of the sea. There are other things which produce movement, such as (1) differences of level, (2) winds, (3) the attraction of the moon and the sun, and (4) occasional causes, like earthquakes and volcanic explosions.

Inequalities of level. The inequalities of level which produce movements of sea-water are brought about chiefly by (1) the inflow of rivers, which raises the surface of the sea near their mouths; (2) winds, which pile up the water along the shores against which they blow; (3) unequal rainfall, which raises the surface most where most rain falls; and (4) unequal evaporation, which lowers the surface most where it is greatest.

Movements due to unequal rainfall and evaporation are too slight to be seen. Those caused by the inflow of rivers and by winds are greater. Thus, beyond the mouth of a great river like the Amazon, movement may be distinct for many miles, and waters often are piled up against a shore by winds, so that the rise is seen readily. The raising of the surface of the water caused most of the destruction in the storm at Galveston (p. 92). When the water-level along a coast has been raised by the wind, it settles back after the wind goes down. Since the causes producing differences of level are always in operation, movements due to these differences are always taking place.

Winds. Winds produce movement of sea-water in another way. Where they have a constant direction, as in the zone of trades (p. 105), there is a constant drifting movement of surface water in one direction. A steady movement in one direction necessitates a return movement somewhere else, thus producing a *circulation* of the sea-water. Where the circulation is in the form of distinct streams of water, they are called *ocean currents.*

Attraction of moon and sun. Bodies attract each other in proportion to their masses, and inversely as the squares of their distances. That is, a body which weighs twice as much as another has twice the attractive force at the same distance. If one of two bodies of the same mass (or weight) is twice as far from a third body as the other is, their attractive forces on the third are as 1:4.

The side of the earth toward the moon is nearer the moon (by

about 4,000 miles) than the center of the earth is, and so is attracted by that body more strongly than the center. The opposite side (about 4,000 miles farther away) is attracted less strongly than the center, and these differences of attraction disturb the waters of the earth. The attraction of the sun produces similar, though lesser, effects. Movements of the sea-water, known as *tides*, are the result.

Occasional causes. Landslides along shore, earthquakes, and volcanic explosions may cause sudden and extensive movements of the ocean-water (pp. 191, 197). Low coastal lands occasionally suffer severely from movements of this sort.

Types of Movement

The principal movements which result from the above causes are (1) *waves*, with the *undertow* and *shore currents* (p. 346) which they produce; (2) *ocean currents;* (3) *drift*, or feeble currents; and (4) *tides.*

Waves. When the wind blows over a water surface it causes waves. The stronger the winds, the greater the waves. With moderate winds, waves in open water rarely exceed 10 feet in height (from crest to trough). Ordinary storm-waves may be twice as high, while in violent storms a height of 40 or more feet is attained. Such waves breaking on the decks of vessels may do much damage. Storm-waves travel 30 to 60 miles an hour, but, save in shallow water, the water in a wave usually does not move forward (p. 346).

The distance between successive wave crests is the *length* of the wave. Wave lengths vary from 100 feet or less, to 2,000 feet or more in severe storms. Occasionally the surface of the ocean is smooth and glassy, and yet shows long, low undulations. These are "swells," and usually represent waves caused by distant storms. On some coasts they interfere seriously with commerce. Short, "choppy" waves are especially unfavorable for small craft, and may cause much discomfort to passengers on larger vessels. In general, the longer the vessel, the less it is affected by waves; hence the advantage of the modern ocean steamships, which in many cases are twice as long (700 to 800 feet) as the average storm-wave.

Currents and drifts. There are more or less distinct streams of water, or currents, in various parts of the ocean. This was known first by their effect on the course of sailing vessels. It was later proved in other ways, as by following the course of floating objects set adrift for this purpose.

The course of currents is important because of their effect on navi-

gation. In foggy weather, and especially near some coasts, failure to allow for the current may lead to ship-wreck. Some of the wrecks that have occurred on the Irish coast probably were caused in this way. Vessels are aided or retarded by currents, according to the direction of the voyage. Surface currents affect the movements of icebergs and floe-ice. Collision with an iceberg may wreck the largest steamship, as the Titanic, and floating ice favors the formation of fog, which increases the danger of collision. For these reasons, steamship routes across the North Atlantic vary somewhat with the season, in order to avoid the floating ice.

Little is known of ocean currents beneath the surface. Most of them are shallow, compared with the depth of the ocean. A current so slow as to be indistinct often is called *drift*.

Courses and causes of ocean currents. Fig. 66 shows the general circulation of the surface waters of the sea. It represents a large part of the surface water as moving. There are *equatorial currents* or drifts moving westward, one on each side of the equator, in both the Atlantic and Pacific oceans. The westward-drifting equatorial waters of the Atlantic are divided at the coast of South America. The smaller part is turned to the southwest, and the larger part to the northwest, along the border of the continent. Part of the northern branch flows through the Caribbean Sea into the Gulf of Mexico, whence it issues through the narrow strait between Cuba and Florida as the *Gulf Stream*. This well-defined current is fed partly by the water which enters the Gulf from the equatorial drift, and partly by that which enters from the land.

In the Straits of Florida, the Gulf Stream is about 40 miles wide in its narrowest part, 2,000 to 3,000 feet deep, and has a maximum velocity of about five miles per hour. Farther north it becomes wider and slower, until, in the open ocean, the rate is perhaps only 10 to 15 miles per day. As it becomes slow, its boundaries become less distinct, and it is recognized by its temperature, color, and life more readily than by its motion.

As it advances, the Gulf Stream turns toward the east (to the right), crosses the Atlantic, and approaches the coast of Europe in a latitude farther north than that where it leaves the coast of America. As it approaches Europe, it divides and spreads, but long before Europe is reached (about latitude 40° N.), the current has become a widespread drift of water, not easily distinguished. This favorable current and the westerly winds make the voyage for sailing vessels from this country to England much quicker than the return trip.

That part of the equatorial drift which is turned southward along the coast of South America soon turns to the left (Fig. 66).

The equatorial drifts of the Pacific follow courses similar to those of the Atlantic. The part which turns north is the *Japan Current.* The Indian Ocean has a south equatorial drift only, and its course corresponds to that of the southern part of the equatorial drifts of the other oceans. All currents moving toward the poles from the equatorial region are *warm currents.*

The movement of warm waters into the polar oceans makes a return movement necessary. Cold waters moving equatorward from these oceans are turned to the right in the northern hemisphere, and to the left in the southern. The result is to throw them to the eastern coasts of the continents, where in places they form distinct *cold currents.* Along the east coast of North America, the *Labrador Current* sometimes brings icebergs south to latitude 40°, while in the warmer waters of the northeastern Atlantic, drift-ice rarely is encountered south of latitude 70°. The Labrador Current chills the air above it, and this helps to make northeast winds in New England cold.

The equatorial drifts are caused and directed by the trade-winds. Outside the tropics the winds do not blow in one direction all the time, and so do not produce persistent drifts or currents. In regions of strong monsoon winds, as about India, the drift of the surface waters changes with the wind.

If the ocean covered all the earth, the westward drift of equatorial waters caused by the trade-winds would go round and round the earth. But the continents deflect the waters, turning them north and south. Once turned in these directions, the waters would tend to follow the coasts but for the deflecting influence of the earth's rotation. Where the sea is so shallow that the moving water touches bottom, the topography of the bottom influences the course of movement. Ocean currents therefore appear to be *started* chiefly by the winds, and to be *directed* by winds, lands, and the rotation of the earth, and, to a less extent, by the topography of the bottom.

Ocean currents and atmospheric temperatures. Without ocean currents, the isotherms over the sea would follow the parallels somewhat closely, except near the continents (p. 51). Under such conditions, the temperature over the ocean in the latitude of the British Isles and northward would be 10° F. or more lower than now (Fig. 65). Ocean currents do not themselves warm or cool the land; but the air over a warm current is warmed by

Fig. 66. Chart showing ocean currents for the world. Arrows indicate direction of flow. Approximate velocity in miles per hour indicated by the number of bars on shaft of arrow.

the water, and is then blown to the land. Even without the Gulf Stream, the western coast of Europe would have a milder winter climate than the eastern coast of North America in the same latitudes (p. 51), but the drift of warm water into the North Atlantic makes the winter temperature of Europe north of latitude 50° considerably warmer than it would be otherwise. Thus the harbor of Hammerfest, Norway, Lat. 76°, is affected by ice little more thán that of New York, Lat. 40°. The Japan Current likewise lessens the cold of winter on the northwestern coast of North America.

Warm currents often help to cause fogs, both at sea and on land. When wind blows over a warm current, it takes up a large supply of moisture. If it then blows over colder water, it is cooled, and some of its moisture is condensed, producing a fog. Fogs are common along the Gulf Stream, especially where the adjacent land or water is much cooler than the current itself. Fogs are more abundant about Newfoundland than farther south, because the difference between the temperature of the Gulf Stream and its surroundings is greater there than farther south.

Tides. Along most coasts the ocean-water rises and falls twice every day, or, more exactly, every 24 hours and 52 minutes. The rise and fall of the water are the *tides*. The tide rises for about six hours, when it is *high* or *flood tide*, and then falls for about six hours, when it is *low* or *ebb tide*. In most places there is a distinct interval of little or no movement ("slack water") when high tide changes toward low, and vice versa. The rise and fall amount to several (3 to 6) feet in most places. In bays which open broadly to the sea, but are narrow at their heads, the range is sometimes 20 or 30 feet, and in rare cases, as in the Bay of Fundy (Figs. 67 and 68), 50 feet or more. Where bays have a narrow entrance and widen within, the tidal range is small. Tides are absent in small lakes, and are feeble in large lakes and in seas connected with the ocean by a narrow passage, such as the Mediterranean Sea and the Gulf of Mexico.

In many shallow harbors the tides have an important effect on navigation (Figs. 67 and 68). Even some of the most important ports depend on the rise of the tide for the movement of their commerce. Thus at Liverpool vessels arriving at low tide must wait, in many cases, for high tide, before the water is deep enough for them to dock, and vessels must arrange hours of departure to match high tides. Where the tide runs in among islands, or passes through narrow straits, it causes distinct currents (*tidal races*), eddies, and whirlpools,

like the famous Maelstrom near the Lofoten Islands. Sailing vessels frequently have serious difficulties with tidal races, as at Hell Gate, New York, and in Vineyard and Nantucket sounds, off the coast of

Fig. 67. Low tide at Wolfeville, Bay of Fundy, Nova Scotia, Sept., 1903. In March, 1904, the end of the pier was washed away in a storm, and the lighthouse was damaged. (Roland Hayward.)

Massachusetts. Fishermen commonly speak of the tide as "coming in," or "going out," and time their movements to take advantage of it. In many ways tides are more important to navigation than ocean

Fig. 68. High tide at the same place shown in Fig. 67. (Roland Hayward.)

currents, and much effort is devoted to charting them for the benefit of navigators.

The tide runs far up many rivers. At Troy, some 150 miles up the Hudson River, the range of the tide is more than two feet, and tides ascend the St. Lawrence nearly 300 miles.

It is at least two thousand years since the moon was first thought to cause the tides, but only about two hundred years since Newton explained how the moon produces them. Without attempting to give a full explanation of the tides, some of the principles involved may be understood. If a weight is attached to a string and whirled, it tends to fly away in a straight line. It is prevented from doing so by the string, which holds it in its circular path. The tendency to fly away is what

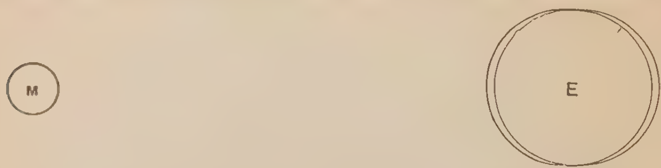


Fig. 69. Diagram to show the tendency of the moon to raise the water on the side of the earth toward the moon and on the opposite side at the same time, producing two high tides.

is called *centrifugal force.* The earth and moon attract each other (p. 147), and would fall together but for the centrifugal force due to their motions. At the center of the earth, and at the center of the moon, the attraction between these bodies is exactly balanced by the centrifugal force due to their revolutions. The result is that neither falls toward the other. But on the side of the earth nearest the moon the attraction is stronger than at the center of the earth (p. 148), and is greater than the centrifugal tendency. *The attraction of the moon, therefore, tends to make the earth bulge out on the side nearest the moon.* On the opposite side of the earth the attraction is weaker than at the center, and is less than the centrifugal force. Here, too, the earth tends to bulge out. The solid part of the earth is so rigid that it does not rise enough to be felt or seen. But the waters of the ocean

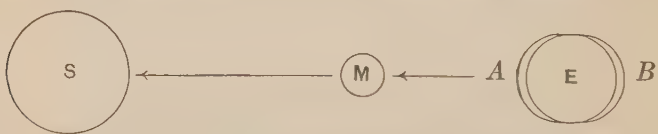


Fig. 70. Diagram to show the relative positions of the earth, moon, and sun, at the time of new moon (=spring tide). Size of moon (M) and earth (E) greatly exaggerated.

move easily, and rise a little, and the rise takes place on opposite sides of the earth at the same time. This makes the *high tides.* Between the high tides the water sinks a little, making the *low tides.* The rotation of the earth makes the tides appear to move about the earth.

If all the earth were covered with water, its surface would have two great tidal bulges or waves at the same time (Fig. 69). The highest part of one would be a point directly under the moon, and the highest point of the other would be opposite the first. Each wave would cover half the earth, and the borders of the two would meet in a great circle, where the surface of the water would be lowest.

If the moon were not revolving about the earth, high tide at any place would come every 12 hours. But the moon moves forward in its orbit about the earth,

so that it takes 24 hours and 52 minutes for a given place to have the same relation to the moon that it had the day before. This makes the period between successive high tides 12 hours and 26 minutes.

The movements of the tides are not so simple as the outline above would imply. Many things interfere. The continents stop or divert the advance of tidal waves, and the waves travel more slowly in shallow than in deep water (Why?). Since tides are retarded most near land, their advance is here most irregular. For these reasons, the time of high tide at most places differs from the time when the moon

Fig. 71. Diagram to show the relative positions of the earth, moon, and sun at the time of full moon (= spring tide).

crosses their respective meridians. This difference in the time of arrival of high or low tide may be determined for any harbor, and is called the "establishment of the port." At New York, for example, high water arrives 8 hours and 13 minutes after the moon passes the meridian. Tables showing the "establishment" of different ports are of great value to navigators.

The sun also attracts the earth, and tends to cause tides. If there were no moon there would still be small tides produced by the sun. The tides which we know

Fig. 72. Diagram showing the tendency of the sun and moon to produce tides on opposite parts of the earth at the time half way between new moon and full moon, and half way between full moon and new moon.

are the combined effects of moon and sun, but the moon's tides are much the stronger. The sun strengthens the tides when sun and moon work together, and weakens them when they work against each other.

When sun and moon stand in the relation to each other and to the earth shown in Fig. 70 (*new moon*), each tends to make high tides at *A* and at *B*. When the relations are those shown in Fig. 71 (*full moon*), the result is the same. At these times, and each occurs once a month, high tides are higher, and low tides lower, than at other times. The tides of such times are called *spring tides*. They have no relation to the spring season.

When the earth, moon, and sun have the relative positions shown in Fig. 72, and this occurs twice each month, the tidal influences of the sun and the moon are

opposed to each other, and the result is that high tides are not so high, nor low tides so low, as under other conditions. The tides of such times are known as *neap tides*. Spring tides have nearly twice the range of neap tides in many places.

In the open ocean and along precipitous coasts, the tide is like other waves, merely a rising and falling of the water. Like other waves also, the water of the tidal wave moves forward when it approaches shores where the water is shallow.

In shallow waters near the coast, tides alternately cover and expose wide expanses of sandy beach or mud flats, as the case may be. The water-line at low tide may be a quarter of a mile or more from its position at high tide. Tidal currents may be effective agents of erosion, maintaining deep channels in harbors, to the great advantage of commerce. By the circulation they cause, tides in some cases help to remove filth which otherwise would accumulate in harbors. Sewage disposal is always easier for cities near tide-water. On the other hand, the sediment drifted about by tides may be deposited in harbors. This makes expensive dredging necessary, in order to maintain a sufficient depth of water for shipping. The frequent shifting of the deposits renders it impossible to indicate the channel on the pilot charts of some harbors.

The large volume of water rising and falling in tides has led to many attempts to develop tidal water power. Small tide-mills are used for grinding grain and other purposes at various places in western Europe, and a few larger power plants have proved useful, as in the Seine estuary.

The Life of the Sea

Animals and plants abound at and near the surface of the sea, and at the bottom where the water is shallow. A bucket of water dipped up from the surface of the ocean almost anywhere will contain hundreds or even thousands of minute plants and animals, though most of them are too small to be seen without a microscope. Living things are present, but not in great numbers, at the bottom of the deep sea; but in the water between the uppermost 100 fathoms and the bottom, there is little life.

The temperature, the depth, the clearness, the saltness, and the quietness or roughness of the water, influence the life which it contains, in ways easily understood. The depth of the water has little or no effect on plants and animals which float or swim near the surface; but at great depths the supply of oxygen is slight, and there

is not light enough so that animals can see much below 50 fathoms. In the great body of the ocean darkness reigns, and green plants, which depend directly on sunlight, cannot live in darkness.

Though the pressure of the water at the bottom of the ocean is very great (p. 143), the animals living there can stand it because their bodies are full of liquids under the same pressure, and these great pressures within their bodies balance the great pressures without. If an animal from the bottom of the deep sea were brought suddenly to the surface it would explode (Why?). Even when raised slowly, they sometimes explode as they near the surface.

Some animals, such as the polyps which make coral, live only in warm regions. Others, such as narwhals and seals, are found only in cold waters. Still others are found in both warm and cold waters. The unequal distribution of ocean temperatures by warm and cold currents influences greatly the character of marine life in different parts of the sea.

In many ways the life of the sea is in strong contrast with that of the land. Thus most familiar land plants are fixed in position, but many sea plants float. Most land animals are free to move about, while many of those in the sea, such as polyps and barnacles, are fixed through most of their lives. Many which are not fixed move about but little, either lying on the bottom or burrowing into it. Some, on the other hand, as many of those in the surface waters, appear to be moving always.

All the great groups of animal life are represented in the sea. Even warm-blooded mammals (whales, seals, walruses, etc.) abound in frigid waters, among icebergs and ice-floes. Some of them, like the seals and walruses, do not spend all their time in the water, but frequently crawl up on the ice or land.

Not only are there many varieties of marine plants and animals, but the largest modern animals (whales) live in the sea. Many sea plants, too, are of great size. Some sea-weeds are six inches in diameter, and some have a length greater than that of the tallest trees.

The total value of food products—fish, oysters, clams, crabs, lobsters, etc.—derived from the sea probably is not less than $500,000,000 per year. The best fishing regions are found where large areas of shallow water, as over broad continental shelves, furnish extensive feeding and breeding grounds for vast numbers of fish. The most important region of this sort is the area of shallow water about the British Isles, including the North Sea. The British fisheries employ

more than 100,000 men, and yield an annual catch valued at more than $50,000,000. Similar conditions led to the development of important fisheries from New England (p. 375).

Other sea animals furnish other articles of commerce. The seal furnishes fur and oil; the whale, oil and whalebone; and the hide of the walrus makes exceptionally strong leather. Coral and sponges, products of animal life, are also articles of commerce. Sea-weed was

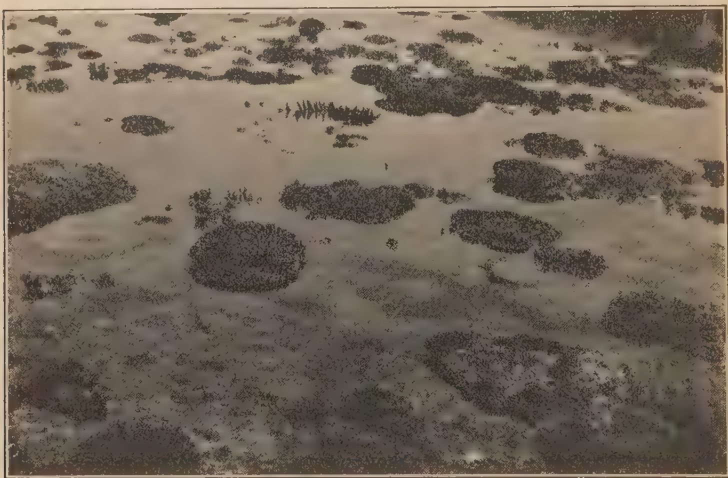


Fig. 73. Coral formations, Samoa. (Muir and Moodie.)

used formerly as the chief source of soda and of iodine. Some varieties still are gathered in large quantities on the coast of Massachusetts and Europe, to be used as food under the name of "Irish moss."

Coral reefs. The little polyps (Fig. 73) which secrete coral live where the water (1) is 120 feet or less in depth, (2) is never colder than about 68° F., (3) has the saltness of normal sea-water, (4) is free or nearly free from sediment, and (5) is subject to some movement by the wind. Where these conditions exist, polyps thrive and make reefs, and the reefs may become islands. Polyps flourish along the borders of many tropical lands, and in some places far from shore.

Coral reefs are of several classes. Those which are separated from the land by a somewhat deep channel or lagoon are *barrier reefs*. Those close to the land are *fringing reefs*. Rudely circular reefs

inclosing a central lagoon are *atolls*. The chief importance of coral reefs is their relation to navigation. Atolls frequently afford shelter to vessels in distress. Submerged reefs, however, are dangerous, and long barrier reefs may hamper commerce seriously, as along the east coast of Australia.

The use of pink or red coral for jewelry leads to important coral "fishing" in the Mediterranean, whence much of the product goes to India. Most of the natives of coral islands are backward in civilization, because of the limitation of their resources.

Questions

1. Why is agriculture possible on a limited scale in Alaska, and not in the same latitudes in Labrador, Greenland, and Baffin Land?

2. Why is Alaska less favorable for agriculture than Norway?

3. Why is the climate in latitude 50°, on the west coast of South America, less favorable for farming than that in latitude 50° on the west coast of North America?

4. Why are isotherms (Fig. 65) affected less by ocean currents in the southern hemisphere than in the northern?

5. Why is the water along the equator in the Pacific Ocean warmer toward the western border of the ocean? What does the principle involved suggest in regard to the surface temperatures in the Gulf of Mexico?

6. Why are steamer routes across the Atlantic farther south in summer than in winter?

7. In order to enter a shallow harbor, is a vessel more likely to have to wait for flood tide at the time of neap tides or at the time of spring tides? Why?

8. On which side of the Gulf Stream, in latitude 45°, are fogs more common? Why?

9. Are fogs more likely to occur over a warm current, or over a cold one? Why?

10. What inference might be drawn from the fact that polyps once lived within the Arctic Circle?

11. What changes in geography are implied by the fact that polyps once lived in eastern Wisconsin?

CHAPTER XIII

THE MATERIALS OF THE LAND AND THEIR USES

General Constitution

The mantle rock. The loose material such as soil, clay, sand, and gravel, which covers most of the land, is called *mantle rock*, because it forms a mantle over the solid rock beneath. Mantle rock varies in thickness from a few inches to scores or even hundreds of feet. It is formed by the decay and breaking up of solid rock, and for this reason is called also *rock waste*.

Soil is the uppermost part of the mantle rock, which serves as a source of food for plants. It varies in thickness from two or three inches to as many feet, and locally, much more. Soil consists of small particles of minerals, usually mixed with partly decayed vegetable matter (*humus*). Both mineral and organic matter are necessary parts of a good soil, but their proportions vary greatly. In color, soil may be yellow, dull red, gray, brown, or, when much humus is present, black. It may be either clayey and compact, or sandy and porous.

In order to support plant life, soil must contain both air and water. Air always is present in sufficient amount, unless crowded out by excess of water, as in some swamp soils. On the other hand, the necessary amount of water may be lacking, as in deserts. Such soils are barren, even though perfect from the physical and chemical standpoints. In western United States, large areas of barren land need only water to be of great value.

In excavations, as for cellars, wells, railway cuts, and the like, soil may be seen to grade down, in many places, into *subsoil*, which is different in color and texture from the soil above. In most places the subsoil is much thicker than the soil, though it may be absent altogether.

Solid rock. Beneath the subsoil is solid rock (Fig. 74). This extends down to great depths, probably even to the center of the earth. In interior United States, solid rocks may be seen chiefly in quarries, mines, along the courses of certain rivers, and in a few

other situations; but in eastern Canada, in western Scandinavia, among high mountains generally, and in many other places, they come to the surface over large areas. Such places have little value from the standpoint of agriculture, even though other conditions are favorable.

Soils

Importance to man. Man depends, directly or indirectly, on soil for most of that which he eats and wears. Products of the soil furnish the principal articles of commerce, and its cultivation con-

Fig. 74. Diagram showing soil grading into solid rock beneath.

stitutes the chief basis of civilization. These relations, too, are lasting ones. Whether the United States shall in the future support a numerous, well-to-do, progressive population, or a sparse, under-fed, and non-progressive one, is largely a question of whether the soil of the country is kept abundant and fertile. In 1900, more than a third of the wage earners of the United States were employed in farming.

The Making of Soils

We have seen that most soils are formed by the decay and breaking up of solid rocks. All changes which make solid rock crumble are processes of *weathering*. The weathering of rock prepares it for transportation by wind and water.

Chemical processes. The oxygen, carbon dioxide, and water vapor of the air are active *chemically*. The meaning of chemical

action is illustrated by the rusting of iron. Iron rust is composed of iron, oxygen, and water. Oxygen and water from the air enter into chemical combination with the iron. While all three of these substances are in the rust, the rust does not look like any one of them. The union of oxygen with any other substance, as iron, is *oxidation.* The union of water with another substance is *hydration.* Iron rust is therefore *oxidized and hydrated iron.*

If rusting is allowed to continue, iron is, in time, "eaten away"; that is, it crumbles to pieces. In this case, as in many others, *chemical change* produces physical change. Many rocks contain iron which may be oxidized and hydrated. When such rocks are exposed to the air, therefore, the iron in them is changed (rusted), and this tends to make the rock crumble. Other chemical changes tend to produce the same result. Some of the substances made by chemical changes in the rocks are soluble, and if they are dissolved and carried away by waters passing through the rock, the rock from which they are taken is left more porous, and weaker. Some rock-making minerals are soluble without chemical change, so that solution is one of the most important means by which rocks are made to crumble, and by which soils are formed.

Fig. 75. Surface of bowlder scaling off under changes in temperature. (Taff, U. S. Geol. Surv.)

Mechanical processes. (1) When water freezes, it expands about one-tenth of its volume, and in doing so exerts great force. When it freezes in rock cavities which it nearly fills, it acts like a wedge, and may pry the rock apart and break off pieces. This process of rock-breaking is most important when there is abundant moisture, and where the changes of temperature above and below the freezing point of water are frequent. Rock-breaking is a first step in the making of soil from rock.

(2) Where solid rock has no covering of loose material, as on many steep slopes, it is heated by day and cooled by night, and the daily changes of temperature may be great. Rocks expand when heated and contract when cooled, and under daily heating and cooling their surface parts break and scale off (Fig. 75). The breaking of cold glass when touched with hot water, or of hot glass when touched with cold water, involves the same principle. The shattering of rock by heating and cooling is very common, particularly in high mountains. Thus the upper part of many a mountain is covered with broken rock (Fig. 76), so insecure that a step may loosen many pieces and start them down the mountain. Great piles of such debris (called *talus*) bury the bases

Fig. 76. Summit of Granite Peak, Wasatch Mountains, showing broken character of the rock. (Church.)

Fig. 77. View showing long talus slopes. (Russell, U. S. Geol. Surv.)

of some mountains to the depth of hundreds of feet (Fig. 77). This debris tends to decay, gradually forming soil, after which, if other conditions are favorable, the slope is occupied by plant life.

(3) The growth of roots in cracks in the rocks may enlarge the openings, and so help to break the rocks (Fig. 78).

(4) The multitudes of burrowing animals make openings in the ground, and bring large quantities of loose material to the surface, where it is exposed to air and water, and is by them changed to soil.

Fig. 78. A tree growing in a crack in the rock. The growth of the tree widens the crack. Sierra Nevada Mountains, California.

(5) Rivers wear the bottoms and sides of their channels, and so help reduce solid rocks to fine material.

(6) Glaciers grind and crush masses of rock into such fine material that some of it is called "rock flour." Much of the mantle rock of northeastern United States was ground up by ancient glaciers (p. 251).

(7) In many dry regions, wind-driven sand wears exposed rocks and forms much fine, loose material, capable of becoming soil.

Classes of Soils

In the paragraphs which follow, the term soil is used to include the subsoil also, where the distinction between them is not important.

Soil which remains above the solid rock from which it was formed is *residual soil* (Fig. 74). On the other hand, *transported soil* has been brought from its place of origin to its present position by some of the agents (wind, water, or ice) which transport materials on the surface of the earth. In general, transported soils are richer than residual soils, though this is not always the case.

Residual soils. All kinds of rock decay, and the decayed rock, properly weathered, becomes soil. Residual soils vary greatly in fertility, much depending on the character of the parent rocks. Thus most sandstones weather into poor soil. Shales produce clay soils of greater average fertility, but in some cases they are heavy, and hard to work. Limestone soils are, as a class, very fertile, but if their

limey constituents are dissolved out, as they may be, the soil is less fertile.

Transported soils. Transported soils are much less uniform in composition and texture than residual soils. In many cases they represent material gathered from a large area, and are entirely unlike the rocks on which they rest. Sediment transported and deposited by rivers is *alluvium*, and soils formed on alluvium are *alluvial soils*. Such soils in the flood-plains and deltas of great rivers, when not too wet, are commonly of great fertility. The rich soil of the great *alluvial fan* (p. 235) of the Hwang-ho, in China, supports one of the densest populations in the world. Ancient civilizations were confined so generally to rich flood-plain soils that the period before 800 B. C. has been called the *Fluvial Period*.

Eolian soils are formed from sand or silt deposited by the wind. Eolian deposits cover large areas in various regions (p. 202). While the sand is loose, and being blown about, it is hardly soil and offers little chance for agriculture. For this reason, part of an extensive area of sand-hills in western Nebraska has been set aside for a National Forest. It is believed that certain trees which can get along with little moisture may be grown there, and that the entire sand area, now almost worthless, may be covered with a profitable forest. Large areas of land have been reclaimed in this way in southwestern France.

Wind has deposited *loess* in certain regions. Loess is a loam, of buff or gray color, coarser than clay, and finer than sand. Soils formed from loess are very fertile when well watered. Some of the best farming lands of the Rhine, Danube, and other European river basins have loess soils. Similar soils occur in some parts of the Mississippi Basin, particularly along parts of the Mississippi and Missouri rivers.

Before the Civil War, the counties of Missouri covered with loess contained a larger percentage of slaves than most of the rest, and grew large quantities of tobacco. The loess-covered counties of eastern and southeastern Nebraska produce most of the corn, wheat, oats, and alfalfa grown in the state. They are settled more thickly, and have more improvements, than most of the rest of the state.

Much of the mantle rock of Canada and northern United States was brought to its present position by the great ice-sheets which once covered the region (p. 251). This material is called *drift*. Soil formed from drift varies much in character and fertility. Some of

it is too sandy and some is too stony to be farmed with success, but much of it is of excellent quality. Since the glacial drift was made not very long ago (as geology reckons time) by the grinding up of rocks of many kinds, the soils made from it are likely to contain all the mineral elements needed for plant food.

The Removal of Soils

Relation of gain and loss. It has been estimated that in the United States it may take, on the average, 10,000 years to form a foot of residual soil (833 years for an inch). Slow as this rate is, it is faster than the average rate at which soil is removed by surface waters, winds, etc. If soil were removed faster than it is formed, the land would in time be without soil, as it is now in some places, espe-

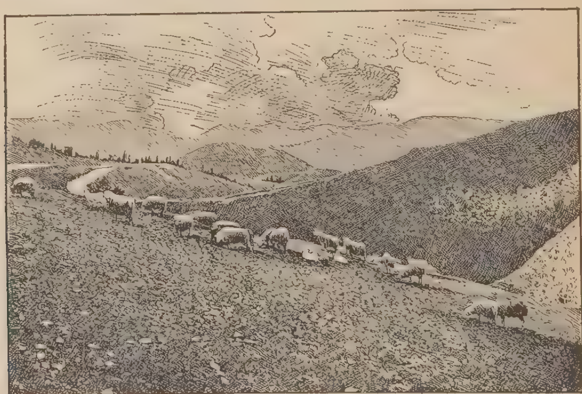


Fig. 79. View in the Apennine Mountains, near Florence. Shows the shallow, stony soil which remains after the loam has been washed away. By removing the slight protective cover of vegetation, the sheep promote further erosion. (Sketch from photograph by Willis.)

cially on steep slopes. With the clearing away of forests and the plowing of land for agriculture, the rate of soil erosion was increased greatly, and it now exceeds the rate of soil formation over large areas. From parts of the Apennine Mountains (Fig. 79), Dalmatia, Palestine, and China (Fig. 80), where the land was cultivated for centuries, the soil has been washed away, and the land is now barren. This shows what must be expected in some parts of this country, if the washing away of soil is not checked. The Mississippi River carries,

on the average, more than 1,000,000 tons of the richest soil matter into the Gulf of Mexico every day. The work performed each year by the Missouri River in transporting material toward the sea is estimated to be equivalent to 275,000,000,000 ton-miles (a ton-mile is a ton carried a mile). All the railroads of the United States carried 218,800,000,000 ton-miles of freight in 1909. The annual loss to the country from the washing and leaching of soil is estimated at some

Fig. 80. View in the western part of the province of Chi-li, China. The erosion has been aided in places by recent deforestation. (Willis, Carnegie Institution.)

$500,000,000. Although the land, even of eastern United States, has been cultivated but a short time compared with that of Europe, yet nearly 11,000,000 acres once farmed have been abandoned. More than one-third of this area has been ruined for farming by the erosion of the soil. It has been estimated that the area thus ruined would, if covered by fertile soil, be capable of supporting a population greater than that of any one of the twelve least populous states. Doubtless the total loss to the country from the *partial* destruction of soil is even greater. Nor is this all. (1) The soil carried away may do much harm where it is deposited. (2) Streams which carry much sediment deposit some of it in their channels, thus interfering with navigation. (3) The clogging of river channels also helps to cause floods. (4) Res-

ervoirs, such as mill-ponds, may be filled with sediment, interfering with manufacturing. (5) Streams are polluted, interfering seriously with their use as a source of water supply for cities, and making expensive filtering plants necessary.

Factors controlling soil erosion. Several factors influence the rate of soil erosion. (1) It is greater on steep slopes than on gentle ones. Lands in the southern Appalachians have been cleared of forests and cultivated where slopes are so steep that the soil was washed away in eight or ten years, and the land abandoned. (2) It varies with the amount and distribution of rainfall. The more the rainfall and the more rapidly it falls, the more rapid the erosion of the soil. The greatest storm of a year may wash away more soil than all the other rains of that year. (3) It is influenced by the presence or absence of vegetation, and in the case of cultivated land by the kind of crop. Bare soils, and those devoted to widely-spaced plants, wash faster than grass lands and forest lands. (4) It is affected by the texture of the mantle rock and solid rock. (Which would favor greater wash, compact or porous soil? Compact or porous material below the soil?)

Fig. 81. Terracing in western North Carolina. (Sketch from photograph by N. C. Geol. Surv.)

Prevention of soil erosion. There are various ways of reducing soil erosion. The more important are the following: (1) Deep and frequent tillage increases the power of the soil to absorb rain, and so reduces the amount of water running directly off over the surface. This is highly desirable apart from its effect on erosion, for few places have water enough to produce maximum crops. (2) Plowing and planting along contours (p. 16) produce little depressions and ridges at right angles to the slope. These tend to check erosion (How?). Plowing up and down a slope, on the other hand, increases erosion (Why?). (3) On steep slopes, wash may be reduced by making a series of terraces or benches. Terracing is practiced in parts of the

Piedmont Plateau (Fig. 81) and elsewhere in the South, and in many countries of Europe and Asia (p. 312). (4) The soil should be kept covered with vegetation as much as possible throughout the year. (5) Grasses tend to prevent wash in several ways (How?). (6) On slopes exceeding 18° or 20° in steepness, the soil is protected best by trees (Fig. 82), and, in general, such land should be devoted to forests. ~~Lessening soil~~ erosion is one of the most important problems of conservation, and it depends very largely on individual land-owners.

Fig. 82. View showing effect of roots in holding soil. San Juan Mountains, Colorado, near Silverton. (Fairbanks.)

Mineral Plant Foods

Proper care of the soil calls for (1) the prevention of erosion so far as possible, and (2) the keeping in the soil of the mineral matters needful for plant food. The mineral substances of importance are phosphorus, potassium, calcium, and silicon, though a few others are used in small quantities. Besides these mineral substances, plants need carbon, hydrogen, oxygen, and nitrogen. Different crops draw unequally on the mineral foods of the soil, and when one crop is grown on the same ground year after year, the soil may become poor in one or more of these foods, and its productivity be reduced. The almost exclusive cultivation of tobacco injured the soil in parts of colonial Virginia. This helped to send thousands of farmers west of the Appalachian Mountains in search of new land. Southern Wisconsin was primarily a wheat region from the 1830's to the 1870's, when the diminishing yields and the competition of the new, rich soils farther northwest led to the raising of other crops, and the adoption of better methods of farming. Where crops of different kinds are raised, one after another (rotation of crops), the soil remains in better condition; but unless the essential elements taken from the soil by plants are returned in some way, its fertility must diminish.

"Worn-out" farms are common in the South and East, and even in parts of the Upper Mississippi Basin. Land may be kept from wearing out by giving it the elements it lacks, that is by *fertilizing* it. In some parts of the southeastern states, where the soil was made poor by the long-continued growth of cotton or tobacco, no crops are grown without the use of fertilizers.

Natural processes tend to add to the soil the substances essential to plants. New soil is formed by the weathering of underlying rocks (p. 161), and ground-waters bring mineral matter in solution from below, which they may deposit near the surface, enriching the soil. In most cases, these processes of soil renewal and enrichment fail to balance the loss which results from the common methods of farming. While certain natural processes tend to enrich soils, surface and underground waters may also erode and leach them (p. 211), thereby reducing their productivity.

The supplies of most of the elements which plants need are abundant in the air, the ground-water, or the soil. Hydrogen and oxygen are the constituents of water, and oxygen makes one-fifth of the atmosphere. The air contains an unlimited supply of nitrogen, but most plants get their nitrogen from compounds of that substance in the soil or in fertilizers (p. 29). Next to oxygen, silicon is the most abundant element in the earth's crust. Most rocks contain a little calcium, and limestone contains much. Carbon is derived from the carbon dioxide of the air. Potassium is a constituent of many common rocks, and there are large deposits of potassium compounds in various places. Wood ashes contain potassium, and for this reason they are good for land.

Unlike the foregoing, phosphorus is a relatively rare element, and already the original amount in the soil has been diminished seriously in many parts of the United States. Guano, chiefly from islands off the west coast of South America, is an important source of supply, though little is imported into the United States. The bones of domestic animals are a second source, and the manufacture of phosphate fertilizer is an important industry at the great slaughtering centers. The bones of buffaloes, killed in great numbers years ago, have been gathered up by the train-load from the western plains and used in the same way. Enormous quantities of phosphorus are now lost in the sewage of great cities, and in the leaching of farm manure. This phosphorus should be returned to the soil, so far as possible. Some European countries are far ahead of the United States in this matter. Finally, the United States possesses the greatest known deposits of phosphate rock (rock containing much phosphorus), and because

phosphorus is to be a critical factor in the fertility of soil, these deposits constitute one of the most important mineral possessions of the nation. In the Southeast, there are deposits in South Carolina, Florida, Tennessee, and Arkansas. The first three of these states furnish nearly all the phosphate rock now mined in the United States. In addition, there are far greater deposits in Idaho, Wyoming, Utah, and Montana. There is, unfortunately, much waste of the poorer phosphate rock in mining — material which, if saved, would be of great value in the future. Unfortunately for the United States, too, increasingly large amounts of phosphate are being exported.

It is not to be inferred from the above discussion that fertility of soil is determined solely by its chemical composition. Its productivity is influenced also by (1) its physical condition (coarseness, fineness, etc.), (2) its water content, (3) the organic matter (humus, etc.) which it contains, (4) the minute organisms (especially bacteria) at work in it, (5) the presence of toxic bodies (the accumulated excreta of plants), and by other factors. Furthermore, the yields obtained from a given soil are affected greatly by (1) the quality of seed sown, (2) the effectiveness of cultivation, and, in many cases, by such things as (3) harmful insects, (4) plant diseases, and (5) weather conditions. The reduced yields of many long-cropped soils probably are due in part to causes other than the impoverishment of the mineral elements of plant food.

General Distribution and Use of Soils in the United States

The principal physiographic provinces of the United States are shown in Fig. 83. Since the settlement and development of these provinces have been influenced profoundly by the topography of the land and the character of the soil, the larger provinces may be considered briefly.

The Atlantic and Gulf Coastal Plains. Much of the Coastal Plain is less than 100 feet above sea-level, though some parts of it are considerably higher. The underlying rocks are imperfectly cemented gravels, sands, clays, marls, and limestones. Along the coast there are extensive marshes, where most of the soil is too wet to cultivate. The draining of these swamps has been begun, as for example on the delta and lower flood-plain of the Mississippi, and when it is completed their rich soils will support many people (p. 301). Elsewhere, the soils of the Coastal Plain present great variety. Over the marls and limestones they are fertile, and over the sands, gravels, and clays, they are much less productive. Many sandy tracts, as in parts of southern New Jersey, have remained wooded and sparsely settled to the present. In the Carolinas such belts, called "barrens," long helped to separate the life of the tidewater country from that of the Piedmont Plateau. In contrast with the sandy areas, the bottom lands of the rivers, where not too wet, and the belts of limestone soils are the garden spots of the South. Here most cotton was grown before the Civil War, and most slaves were owned (p. 325). Here the negro population is densest to-day. It probably is true that the rich soils of many parts of the Coastal Plain, and the genial climate of the South, were responsible for the continuance of slavery in the United States to the time of the Civil War.

The New England Hills. There is no continuous coastal plain in New England. The most important lowlands have developed on weak rocks in the Connecticut Valley, about Narragansett Bay, and around Boston. On these lowlands the early history of Connecticut, Rhode Island, and Massachusetts centered. To-day, the Boston Basin contains about half the people of Massachusetts, and one-fourth those of all New England. Apart from these lowlands, most of New England is hilly. Much of its glacial soil is thin and poor, and in many places stony. It has been estimated that in some parts it took, on the average, one month for a man to remove the stones from each acre of glacial drift, to get it ready

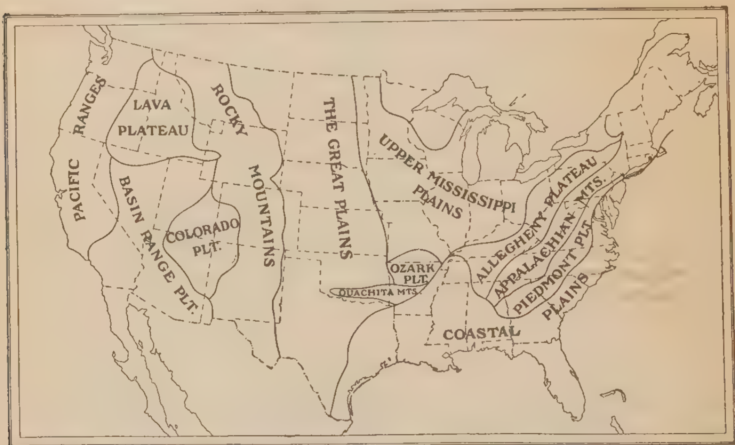


Fig. 83. Map showing the principal physiographic subdivisions of the United States.

for farming. Many of the early settlements were made in areas of stratified drift (p. 266), where the bowlders were fewer and the land flatter.

The unfavorable soils and the harsh climate prevented a high development of agriculture in New England, which was without a single staple crop for export, such as colonial Virginia had in tobacco, and South Carolina in rice and indigo. By the close of the seventeenth century, more than half the people of New England were engaged in industries other than agriculture, and it is said also that more than half the time of the farmers was given to non-agricultural work. For two centuries the life of New England was dominated by industries centering in the ocean—chiefly fishing, shipbuilding, and the carrying trade. Later, manufacturing became the leading interest.

Crude methods of agriculture in early days led to the exhaustion or partial exhaustion of many lands which were originally good for farming. When the lands ceased to produce good crops they were deserted. Much has been written and said of the abandoned farms of New England, but in recent years many of them have been brought under cultivation again, and with the improved methods of to-day they are producing satisfactory returns. It seems certain that many of the

abandoned farms will be reclaimed. Much of the rough, infertile upland, however, probably can be used to best advantage in the future for forests.

The Piedmont Plateau. The Piedmont Plateau has an elevation varying from 250 or 300 feet at its eastern edge, to about 1,000 feet in places along its western margin. The higher lands have a rather poor, residual soil, but many of the valleys have rich, alluvial bottoms.

The Appalachian Mountains. The soils of the larger valleys are fairly fertile. This was strikingly true, originally, of the limestone soils of the Great Appalachian Valley, which, under various names, extends from Georgia to New York. This great valley was one of the first areas west of the Blue Ridge to be settled, and it soon became an important grain producing section. During the Civil War, the Confederate armies drew large quantities of supplies from its fertile fields.

The upper slopes of these mountains are steep, and covered with soil which washes easily when the forest is removed. A National Forest is to be established in the southern Appalachians, and the steeper land devoted permanently to forestry. In the future, the country must look to Appalachian forests for much of its supply of hardwood.

The Cumberland-Alleghany Plateau. The surface of this plateau is much dissected by valleys cut in the nearly horizontal layers of rocks. In general, relatively level land and fertile soil are found only in the valley bottoms. The hills have steep slopes, and their soils are infertile. Except where mineral resources have attracted settlers, the plateau is sparsely settled.

Lake and Prairie Plains. Most of the surface of this area is covered with glacial soil (Fig. 170), the composition of which is influenced greatly by the nature of the underlying rocks. Thus in Michigan and Wisconsin there are large areas of sandy drift over sandstone, where attempts at farming, following the removal of the pine forests, have met with little success. There are also hilly belts (*moraines*, p. 258) in the northern part of the area, where the stony soil is used largely for wood-lots and pasturage. There is also much marsh land, unfit for agriculture until drained. In general, however, the soils of this region, especially the prairie soils between the Missouri and Ohio rivers on the south and southwest and the Great Lakes on the north, are of great fertility. No other equal area in the United States is so important agriculturally (Fig. 257). Iowa, Illinois, Ohio, and Indiana, in the order named, are the first four states in the percentage of improved land to total area.

The prairies generally were avoided by the first settlers, who regarded the absence of trees as evidence of poor soil. Even after their fertility was known, the larger prairies were not settled far back from the main streams until the building of railroads provided means of transportation.

The Great Plains. The surface of this province rises from an elevation of about 1,000 feet at the east, to more than 5,000 feet at the west. Most of the region has a deep and rich soil. At the north, the soil is of glacial origin (Fig. 170); farther south it is (1) partly alluvial, having been spread widely by depositing rivers flowing eastward from the Rocky Mountains, (2) partly residual, and (3) considerable areas in the eastern part of the tract are covered with loess (p. 165). The eastern part of the area is very productive, but the western part has too little rain for ordinary farming. Here agriculture must depend on (1) irrigation, which is possible over small areas, (2) "dry farming" (p. 329), and (3) the cultivation of drought-resisting plants, such as durum wheat and kaffir corn. Over large areas grazing probably will continue to be the chief interest (p. 329).

The Rocky Mountains and Western Plateaus. In the different parts of this great region all kinds of rocks are found, in all sorts of positions. The soils vary as greatly as the rocks, both in origin and composition. Glacial soils are found at the north, and throughout the region in many mountain valleys. Great areas

Fig. 84. Map showing the best use to which it is thought the land throughout North America may be put. (Zon, U. S. Forest Service.)

of alluvial soil fringe the bases of many of the mountains, where withering streams from the uplands have deposited their sediment. Some of these deposits have a thickness of hundreds and even thousands of feet. The steep slopes are flanked also by great piles of talus (p. 163), most of which do not support much plant life. Where the mountain slopes are not too steep, there are residual soils, and these also cover great areas of the plateaus.

Over most of the region, systematic tillage of the soil has not been possible because of (1) too great height, (2) the steepness of the slopes, or (3) lack of adequate rain. Most of the land is therefore best suited to grazing, and, especially in the mountains, to forestry. Irrigation is making agriculture possible in many rather small areas (p. 293), especially in valleys and on other lowlands. In some such places, there is a dense population. Nowhere else in the world is fruit-raising carried on more intelligently or with better results, and probably nowhere else in the world has farm land sold at such high prices. Small, choice orchards have been sold at $4,000 and $5,000 per acre, and prices half as high are not rare.

The Pacific Ranges. As farther east, the soils of the mountain slopes can be used best for forests, for which, except at the south, there is enough rain. Among the mountains there are many fertile valleys with glacial or alluvial soils, and between the ranges are the great waste-filled valleys of the Willamette River and of central California. The rich, alluvial soils of the latter probably have given the state larger returns than its gold mines. In the southern part of the province, the value of even the best soil depends on irrigation, and unfortunately there is water enough to irrigate only about one-tenth of the land. Irrigated land, with groves of oranges or lemons, sells for very high prices, while non-irrigable land is worth but little. Toward the north, with increase of rainfall and with lower temperatures, the necessity of irrigation is less.

Fig. 84 shows, in a general way, the best use to which it is thought the land throughout North America may be put, and serves to illustrate many of the larger points stated in the preceding paragraphs.

Mineral Products and Their Uses

Building Stones and Clay

Building stones. The principal building stones are granite, limestone, marble, slate, and sandstone, though not all rocks of these kinds are useful for building. The strength of the rock, its color, ease of splitting and dressing, and durability all enter into the problem. Not all good stone is available, for much is too far from a market. Cement is taking the place of building stone to a very large extent.

Granite is distributed widely in the United States, and is quarried in a large way in several of the Atlantic States. *Limestone* is quarried in many states, largely for local use. From a few famous quarries, such as those at Bedford, Indiana, it is shipped to all parts of the United States. Much limestone is burned for lime, and much is used for mortar, cement, railroad ballast, etc. The growth of the

cement industry has been remarkably rapid. In 1890, the United States produced less than 350,000 barrels of Portland cement; in 1911, more than 79,500,000 barrels. Much *marble* is used as an ornamental building stone. Until recently, it has been quarried on a large scale only in the East. Vermont supplies about four-fifths of all the marble used in the United States for ornamental work, but Colorado promises to become a great producer.

Slates are used chiefly as roofing material, but also for various other purposes. The production of slate, like that of marble, is confined largely to the East, and is most important in Pennsylvania, Vermont, and New York. *Sandstone* is used for buildings, bridges, and other purposes. It is distributed widely in many states, so that many small quarries serve local needs. A few popular kinds of sandstone, such as the brownstone from Pennsylvania and the vicinity of New York City, have wider markets.

Gypsum is used extensively for building-plaster and certain cements. It is used also as a land fertilizer, and in other ways.

Clays and clay products. Clays have a wider distribution than most other economic rock materials, and are used in making many things. Among these are pottery of various grades, tiles, terra cotta, brick, and Portland cement (made from a mixture of clay and lime rock). Every state produces clay products, Ohio, Pennsylvania, New Jersey, and Illinois leading in the order named. The total value of the products of the clay-working industries of the country exceeded $162,000,000 in 1911.

Substitution of mineral products for wood. Brick, stone, and cement are being substituted more and more for wood in buildings, sidewalks, bridges, piers, etc. This is highly desirable, because these materials are (1) more durable, (2) less liable to fire, and (3) their use lessens the drain on the forests.

Mineral Fuels

Coal. After soil, coal is the most important of the mineral resources. Together with iron, which is next in importance, it has made possible the extraordinary industrial development of the United States. Germany and England also have become great manufacturing nations largely because of their extensive deposits of coal and iron. The United States has more and better coal than any other country, so far as known. Fig. 85 shows the general distribution of its coal fields. Their combined area is about 500,000 square miles,

or about 16 per cent of the area of the country. Their wide distribution is a matter of great importance, since the largest item in the cost of coal is the cost of transportation. The amount of coal in the United States at the beginning of 1911 was estimated at more than 3,062,800,000,000 tons. About one-third of this, however, is accessible only with difficulty, and by no means all of it is of good quality.

Fig. 85. Map showing general distribution of coal fields in the United States. (U. S. Geol. Surv.)

It is estimated that more than 99 per cent of the original supply of coal in the United States is still in the ground.

The mining of coal in the United States began to be important about the middle of the last century, and the output has nearly doubled each decade since. The 496,000,000 tons mined in 1911 was about 1/17 of all mined to the end of that year. If the output should continue to increase at the same rate, the entire known supply would be exhausted in less than 150 years. For various reasons, however, our supply of coal will last much longer than this. Nevertheless, it is highly desirable (1) to avoid, so far as possible, the waste of coal; (2) to substitute water power for steam power (generated by the burning of coal) wherever practicable; and (3) to use coal in the most efficient way possible. The waste in mining coal has amounted to about 50 per cent of the quantity produced; that

is, about 250,000,000 tons were wasted in this way in 1911. This is more coal than was mined in the United Kingdom (the second coal-producing country) in 1905. Much unburned coal passes off as smoke. The average steam engine does not develop into power more than 6 to 10 per cent of the heat energy of the coal. In making electric light from coal, only a small part of one per cent of the energy of the coal is utilized. Much of this waste can be

Fig. 86. Map showing general distribution of petroleum and natural gas fields (the black areas) of United States. (Day, U. S. Geol. Surv.)

avoided, and some progress in this direction has been made already. One effect of the burning of large quantities of coal is to increase the amount of carbon dioxide in the air (p. 30). Indeed, it has been estimated that the amount may be doubled in this way in the next 1,500 years. It will be remembered (p. 31) that this probably would make the climate much milder.

Pennsylvania, West Virginia, Illinois, and Ohio lead in mining coal. They have produced about ¾ of all the coal mined in the United States.

Petroleum. Petroleum was discovered in large quantities in western Pennsylvania in 1859. The field which includes this original area extends from New York to Tennessee (Fig. 86), and has produced more petroleum than any other. The output is now decreasing,

however. Most of the petroleum of this field is of high grade. The large Ohio-Indiana field was the second to come into use (about 1885). Most of the others are of recent development. In 1911, California produced most petroleum, and Oklahoma and Illinois ranked second and third. The total output of the country during this year was more than 220,000,000 barrels. Since 1860, as much petroleum has been produced each nine years as in all preceding years, and should this rate continue, the supply, so far as it can be estimated in known fields, would be exhausted by about 1935. Should the present output continue without increase, the calculated supply will last until about the year 2000.

Crude oil is used for fuel, for the prevention of dust on roads, and for some other purposes. From it various oils are manufactured for lighting and lubricating purposes, and many by-products are obtained. In view of the probable early exhaustion of the supply, petroleum should be used only for those purposes for which it is best adapted. Its most essential use is for the making of oils for lubricating the bearings of all kinds of machinery. For this purpose, no satisfactory substitute is known. On the other hand, the use of petroleum as fuel in locomotives and for the development of power in factories is in most places unnecessary, and should be discouraged.

Natural gas. Natural gas is the most perfect fuel. So far as known, the United States has a greater supply than any other nation, and it occurs in more than half the states (Fig. 86). It is believed, however, that the natural gas now known will be exhausted within the next twenty-five or thirty years. In spite of this, and in spite of its great value, enormous quantities (estimated at 1,000,000,000 cubic feet daily) are allowed to escape from the ground unused. A large part of this waste can be prevented.

Metals

Iron. Some iron was mined in this country in the colonial period. The production was unimportant, however, till 1850. Since then it has increased rapidly, so that the output during the decade ending with 1909 amounted to 52.6 per cent of all the iron ore that has been mined in the United States.

It was estimated recently that the *available iron ore* (that usable under existing conditions) in the United States amounts to nearly 4,800,000,000 long tons (a long ton is 2,240 lbs.), and that in addition there are low grade ores, part or all of which will be useful in the future,

amounting to more than 75,000,000,000 long tons. Like coal, iron ore is distributed widely (Fig. 87), but by far the most important deposits of our country are in the Lake Superior region, especially in northern Michigan and Minnesota. This district contains about 73 per cent of the available ore of the United States, and about 95 per cent of the low-grade reserve. It had produced, to the end of 1911, more than 530,000,000 long tons of iron ore—considerably more

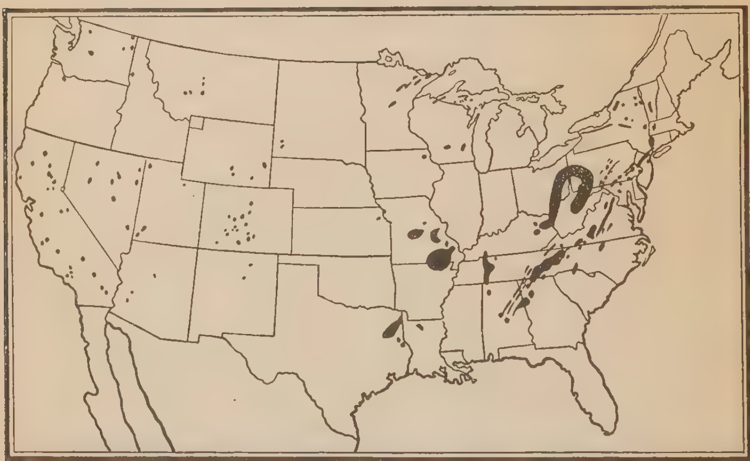


Fig. 87. Map showing general distribution of iron ore in the United States Some of the smaller areas contain more and richer ore than the larger ones.

than half the total amount produced in the United States. In recent years it has furnished about 80 per cent of the entire output of the country. In 1910, the United States produced more than 56,800,000 long tons of iron ore—nearly half the world's production for the year. In 1911, however, the output was only about 41,000,000 tons.

If the iron ores of the United States continue to be mined at the increasing rate of the last few decades, the known deposits of high grade will all be mined in about ninety years. Several considerations, however, make it certain that the supply of ore will last much longer. Furthermore, iron, unlike coal, can be used again and again. For example, old rails are made over into new ones or into other things. The great problem in conserving the supply of iron is therefore to use it again and again, keeping the stock as nearly intact as possible. There is little waste of iron ore in mining.

Copper. The existence of copper on the southern shore of Lake Superior (Keweenaw Point) was known to the Indians at an early date. As late as 1845, however, the entire output in the United States amounted to only 100 tons a year, and not till 1867 did copper begin to be used in large amounts. Its use has increased rapidly in recent years, about 550,000 tons being produced in 1911. Nearly three-fifths of the entire amount produced in the United States have been mined in the last ten years. Michigan, long the leading copper state, is now outranked by Arizona and Montana. Some nine other states, most of them in the West, produce copper, several of them in large amounts.

Copper ores are scattered so widely, and are so irregular in their occurrence, that the supply has not been estimated accurately. It is thought, however, that the *known* copper ore, usable at existing prices, will be exhausted in Michigan in fifteen or twenty years, and in Montana and Arizona in even less time. Should the value of copper increase, lower grade ore could be used. Even now, at the Michigan mines, only twenty-two pounds of copper are obtained, on the average, from each ton of ore. New discoveries of copper are made from time to time, and for this and other reasons, copper ore will last much longer than the time suggested above.

Copper is used chiefly for making wire and brass. These uses involve little unavoidable waste, and the same copper may be used repeatedly.

Gold. The production of gold was unimportant in the United States until after its discovery in California in 1848. The leading gold-producing states are California, Colorado, and Nevada. Each produces about 1,000,000 ounces (an ounce is worth about $20) of gold per year. Alaska is also a heavy producer. The amount of gold which remains to be mined cannot be estimated. It already is practicable to mine very low grade ore. In some cases, for example, a ton of ore is mined and milled to recover one-eighth of an ounce of gold. Gold is used chiefly as coin and bullion, and in the arts. Most of its uses involve little waste or loss of the gold itself. Even were the supply used up, the loss would be much less serious than that of coal or iron.

Silver. Neither the amount nor the duration of the silver deposits of the United States can be estimated. Nevada, Montana, and Utah are (1910) the leading silver-producing states, followed by Colorado and Idaho. Like gold, silver is used chiefly for coin and

in the arts. Its use in photography is an interesting and a rapidly increasing one. In general, there is little waste or loss in its use.

Lead and zinc. Lead was known to the Indians of the Mississippi Valley before the coming of the whites, but the deposits of the region were not worked effectively until the early 1820's, when a period of great activity in mining began. This culminated in Illinois and Wisconsin about 1845. During the next few years many of the miners went to the iron fields of Lake Superior, and to the gold fields of California. Lead was discovered later in various western states, in many places in association with silver. Missouri is the leading lead-producing state, followed by Idaho and Utah.

The known supply of lead is very limited. Much is lost needlessly by the prevailing methods of mining, milling, and smelting. About one-third of the lead produced in the United States is used in making paint. Lead used in paint can be used but once, and more abundant things will have to be substituted for it increasingly in the future.

Zinc is associated in many places with lead, and for years was regarded as valueless by lead miners. The first zinc plants were erected in Illinois in the 1850's, but for twenty years the production was small. In recent years it has increased very fast, and the output of the last decade equaled that of all earlier years. Missouri leads, by a large margin, in its production. There is great waste of zinc in mining, concentrating, and smelting. About two-thirds of that produced in this country is used for galvanizing iron. Like lead, it is used also for making paint. Most of the rest is used (with copper) for making brass, and for sheet zinc.

In 1911, the United States produced 406,000 tons of lead and 271,000 tons of zinc.

Aluminum. Aluminum is by far the most abundant of the metals. It is a constituent of many rocks, and makes up more than 8 per cent of the earth's crust. It is light, strong, malleable, ductile, is a good conductor of electricity, takes and retains a high polish, and does not corrode easily. These properties fit it for many purposes, but the difficulty and expense of separating it from its combinations long prevented its extensive use. It is extracted on a commercial scale only from *bauxite*, a relatively scarce mineral. When it can be obtained cheaply from clay, of which it forms a part, its use will be increased enormously.

The production of aluminum in the United States increased from 83 pounds in 1883 to about 47,000,000 pounds in 1911. It is used for making a constantly increasing variety of things, such as cooking utensils, castings, wall "paper," ceiling panels, paints, varnishes, and wire. Doubtless in the future it will replace iron, copper, and some of the other metals for many purposes.

Salt

Salt is indispensable to man, and fortunately the supply is practically inexhaustible. (1) In arid regions there are many lakes with no outlets into which streams bring minerals (including common salt) that have been dissolved during the passage of the water through or over the rocks (p. 211). These things are left behind as water evaporates from the lake, which becomes more and more saline as the process continues. When the waters of the lake become saturated, further evaporation causes the minerals to begin to be precipitated from solution. Great Salt Lake is estimated to contain some 400,000,000 tons of common salt. (2) Extensive salt beds which were laid down in ancient lakes or arms of the sea are found between beds of other rock in many places. Those in central New York may have an area underground of some 10,000 square miles (larger than Vermont), and single beds are in places 80 feet thick. Besides New York, Michigan and Kansas are leading salt-producing states. (3) The ocean is the remaining and greatest source of supply (p. 144).

The need of salt helped to hold most of the American colonists near the Atlantic coast for a long time. Not until it was discovered in the Holston and Kanawha valleys (Tenn. and W. Va.), in central New York, and in Kentucky, did dependence on the coast for salt cease. In 1778, salt brought on pack animals over the Appalachian Mountains sold in southwestern Pennsylvania for £6 10s. per bushel. The same amount of salt now is worth but little more than 10 cents where it is prepared, and not more than 50 cents in the markets in most parts of the United States.

Conservation of Mineral Resources

The mineral resources noted above are a part of the heritage of the earth. The people of to-day have a right to use such of them as they need, in as great quantities as necessary. It is their duty, however, to use them in such a way as to insure the minimum of waste and the maximum of efficiency. This is demanded alike by the interests of the present generation, and by those of genera-

tions to come. The facts given show that many reforms are needed. The reckless waste of some of these resources is a reflection upon American intelligence.

Questions

1. What are the principal ways in which soil is being formed in New England? Florida? Nevada?

2. Why are the soils of the lower flood-plains and deltas of large rivers of great fertility in most cases? Are they commonly of coarse or fine texture? Why?

3. State conditions which explain why soil wash is, in some cases, much faster on one of two equal slopes than on the other.

4. Would you expect wash in winter from bare fields to be greater in northern or southern United States? Why?

5. Would it be desirable, from the standpoint of agriculture, entirely to prevent soil erosion if it were possible? Reasons?

6. Tile underdraining is in many cases effective in checking soil erosion. Why?

7. Plowing under straw, leaves, etc., was formerly a common practice. What value, if any, would this have?

8. In some of the mountainous areas of Italy, Austria, and other countries, forests are maintained in strips at right angles to the slope of the surface, while the land between is tilled. Why is this advantageous?

9. Explain in detail why plowing up and down a hill-side is unwise.

10. Other things being equal, would you expect crops to suffer more from protracted droughts on sandy or on clayey soils? Why?

11. In parts of China it is customary to plant alternate rows of leguminous plants (like peas and beans) and grains. How does this benefit the soil?

12. Steel cars rapidly are replacing wooden ones, and re-enforced concrete (i.e., cement strengthened by steel) is being used for many new bridges in place of steel. Are these changes desirable from the standpoint of the conservation of natural resources? Reasons?

13. Why are gold and silver, the "precious metals," much less essential to man than coal and iron?

CHAPTER XIV

CHANGES OF THE EARTH'S SURFACE DUE TO INTERNAL FORCES

Slow Crustal Movements

Except for occasional earthquakes and landslides the crust of the earth seems to be firm and stable, but it is in reality subject to very slow movements which, in the course of ages, produce great changes. Such movements warp both land and sea-bottom. It is probable that more of the earth's surface has been sinking or rising in recent geological times than has been standing still.

Movement of coastal lands. (1) Old buildings and docks, near sea-level when built, are now under water in some places and well above the sea in others. Clearly, this means a recent change, at these places, in the relations of land and sea. (2) Beds of sediment containing sea-shells, deposited beneath the sea in recent times, are found above the water in north Greenland, on the Pacific coast of the United States, in the West Indies, on the west coast of South America, and in other places. On the slopes of Mount St. Elias, Alaska, modern sea-shells have been found attached to the rocks just as they once grew, but several thousand feet above the sea. (3) On the other hand, there are drowned forests along some coasts. Thus north of Liverpool, England, many stumps may be seen at low tide standing on the beach (Fig. 88). Since trees of the kind represented by these stumps do not grow in salt-water, it is clear that the land where they grew has sunk below the level of high water. On the coasts of New Jersey and North Carolina, too, there are stumps having similar histories, several feet below sea-level. These and many other facts prove that the land and sea change their relations to each other, and that most coast-lines have been affected by such changes in recent times.

The emergence of land may be due to (1) its rise, or (2) the sinking of the sea-level. Similarly, the submergence of land may be due to (1) its sinking, or (2) the rise of the sea. From what is now

known it is certain that both the sea and the land rise and fall from time to time.

Causes of changes in sea-level. Several things may make the sea-level rise or fall. (1) The sinking of a part of the ocean bed would lower the sea surface, while the elevation of a part of the sea floor would have an opposite effect. (2) Sediment washed from the land into the sea builds up the ocean floor, and so raises the surface of the sea. (3) Lavas poured out from volcanoes beneath the sea, and the deposits of corals and shell-bearing sea life, make the sea-level rise. (4) An increase or decrease in the total amount of land-water or ice would lower or raise the surface of the ocean. Since the oceans are all connected one with another, each of the above changes would affect the surface of the sea everywhere, and by the same amount. Other factors also affect the surface of the sea, and some of them make it higher in certain places than in others.

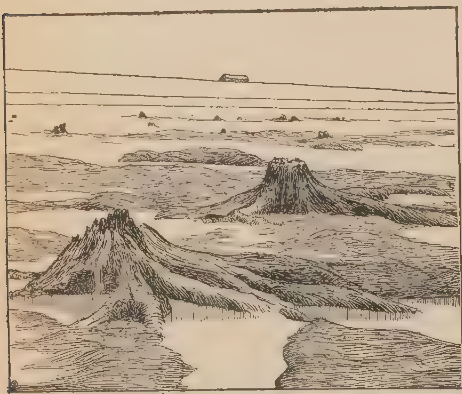


Fig. 88. Stumps laid bare on the beach at low tide; Leasowe, England. (From photograph by Ward.)

Changes of level in the interiors of continents. Changes of level are perhaps as common in the interiors of continents as along coasts, but they are not detected so easily, since there is no level surface like the sea with which to make comparisons. There are raised beaches about many lakes, as about the Great Lakes and Great Salt Lake (Fig. 89); but raised beaches about a lake may result from the lowering of the lake, either by the cutting down of its outlet or by evaporation. They do not, therefore, prove a rise of the land. But many old shore-lines about lakes are not horizontal, as they were when formed. Some parts of the old shore-line about former Lake Bonneville (the ancestor of Great Salt Lake) are 300 feet higher than other parts of the same line. Similar tilted shore-lines are found about many lakes, and show that the land has warped since the shore-lines

were formed. Other phenomena, some of them discussed later, also show movement of large interior areas.

Ancient changes of level. Layers of rock, deposited long ago as sediment beneath the sea, are now found over great areas, far above sea-level. Most of the solid rock beneath the Mississippi Basin, for example, was laid down as sediment beneath the sea, as shown by the shells of the sea animals which it contains. In the

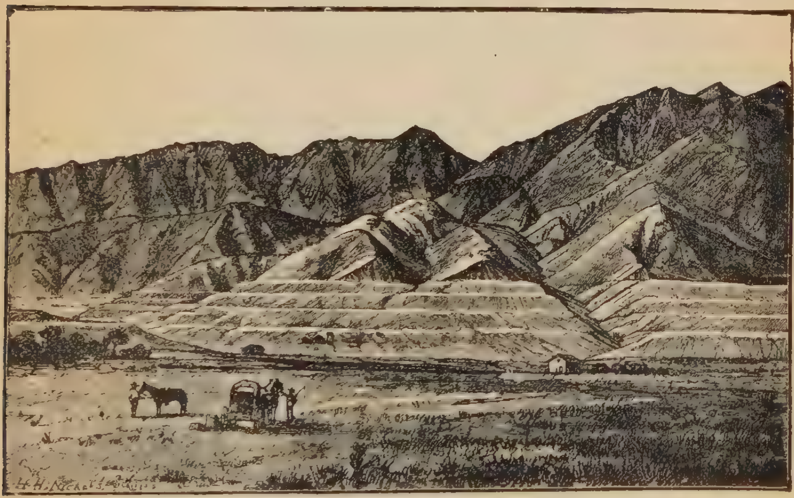


Fig. 89. Shore of former Lake Bonneville, Utah. (From photograph by U. S. Geol. Surv.)

Appalachian Mountains, rocks formed in the same way are found up to heights of several thousand feet; in the Rocky Mountains up to 10,000 feet and more; and in some other mountains to still greater heights. It is certain, therefore, that changes of level have been great, and that vast areas have been affected.

It is also certain that great changes in the areas and in the relations of land and sea have occurred many times in the distant past.

Earthquakes

Frequency and importance. Tremblings or quakings of the earth's surface occur frequently in many countries. Most of them are not felt, and can be detected only by means of delicate instru-

ments made to record them. For many years an average of several earth tremors a day have been recorded in Japan, and it has been said that some part of the earth's surface is shaking all the time. The changes made in the surface of the land by earthquakes are slight, and they are important chiefly because severe earthquakes may cause great loss of life and property.

Distribution. Most earthquake regions lie near the edges of the continental platforms, though some (in Asia) are far inland. Most of them are mountainous areas, though some are lowlands. Earthquakes are perhaps most common in volcanic regions, though not all the earthquakes of such regions have been caused by volcanoes. Except along the west coast of South America, the southern continents are rather free from earthquakes, or at least few are reported from them. In the northern hemisphere, earthquakes are most common about the Mediterranean Sea, in southern Asia, in the islands east and southeast of that continent, and along the western coasts of North and Central America. Some of the areas most affected by earthquakes are settled densely.

Fig. 90. Fissure in floor of Kilauea, Hawaii.

Causes of earthquakes. Earthquakes are caused in various ways. During movements of the earth's crust, great cracks or *fissures* sometimes are formed in the surface of the land (Fig. 90). The walls of fissures may be displaced, or *faulted*. Faulting has caused many great earthquakes, the slipping of one great body of rock past another producing vibrations, which in some cases have spread great distances. An Alaskan earthquake in 1899 was caused by a sudden displacement of more than 40 feet, and the San Francisco disaster in 1906 resulted from a horizontal movement of 5 to 20 or more feet, along a line many miles in length. Earthquakes accompany violent volcanic eruptions, and in these cases the explosions which accompany the eruptions

doubtless cause the quaking. Great landslides and avalanches may cause slight earthquakes. Slight shocks may be caused in still other ways.

It is probable that most earthquakes are incidents of the widespread movements to which the crust of the earth is subject, movements which are due chiefly to the continued fitting of the outside of the earth to a shrinking interior. In general, these movements are too slow to produce vibrations which we can feel; but they are sufficient, in rare cases, to produce great earthquakes.

Destruction of life and property. Except along the plane of slipping, the actual movement of the land surface during an earth-

Fig. 91. The new library building at Stanford University, after the earthquake of April, 1906. (Moran.)

quake is very slight, in most cases only a small fraction of an inch. It is the suddenness of the shock which overthrows and destroys buildings and other objects. That a sudden but very slight movement of the ground may do this is clear from the fact that a quick, sharp tap on the side of a table may overthrow all loose objects upon it, even though the movement of the table itself is very slight.

Some earthquakes in thickly settled regions have caused an appalling loss of life and property. The most disastrous earthquake in North America occurred in and about San Francisco in April, 1906. A large part of the city was burned by the fire which followed the shock. More than 700 lives were lost, and between 100,000 and 200,000 people were made homeless. Some 25,000 buildings (Fig. 91)

were destroyed in the earthquake and fire, having an estimated value of more than $100,000,000. In 1905 a great earthquake in India

Fig. 92. Taal Volcano, Philippine Islands, in eruption. (Gilchrist.)

destroyed nearly 19,000 lives and more than 112,000 buildings. About 100,000 people were killed in the earthquakes in southern Italy in 1908.

In some countries where earthquakes are frequent, like Japan, much attention has been given to making buildings in such a way as to withstand the shocks. The greater frequency of earthquakes in Nicaragua was one reason for selecting the Panama route for the Isthmian Canal.

When an earthquake disturbs the sea-bottom, waves are set in motion. These waves rush upon neighboring coasts, and in some cases (e. g., in Sicily in 1908) they have done great damage. Millions of marine animals and plants were killed during the Alaskan earthquake of 1899.

Vulcanism

Volcanoes

A volcano is a vent in the earth's crust out of which hot rock comes (Fig. 92). The hot rock may flow out in liquid form (called *lava*), or it may be thrown out violently in solid pieces. It is generally built up into a cone (Fig. 93), which may become a mound, a high hill, or even a high mountain. Quantities of gases and vapors are discharged along with the hot rock. There is a hollow, called the *crater*, in the top of most volcanic cones. Craters vary greatly in size, some of the larger ones being two or three miles across. While the volcano is active, an opening leads down from the crater to the source of the lava, at an unknown depth.

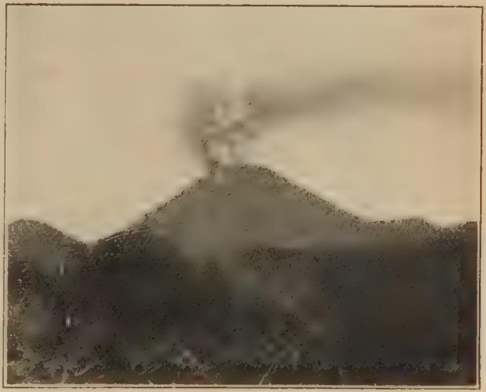


Fig. 93. Cone of Ngauruhoe, New Zealand. (Marshall.)

Common phenomena of an eruption. In the *explosive type* of eruption, rumblings and earthquake shocks, due to explosions within the throat of the volcano, may occur for weeks or months before a violent outbreak. During a violent outbreak, dust, cinders, and larger pieces of rock are shot forth and fall on the sides of the cone. The clouds of condensed steam and dust rising from the crater darken

the sky, and torrents of rain, falling on the fine dust, may form rivers of hot mud. Liquid lava may or may not accompany the discharge of solid material. In the *quiet type* of eruption, the lava rises in the crater and overflows its rim or, more often, breaks out through cracks in the side of the cone. There is little or no burning in a volcano, for there is little or nothing to burn. There is, therefore, no smoke. What appears as smoke is mostly cloud, blackened by volcanic dust.

The products of volcanoes. *Lava* is a term applied both to the liquid rock which issues from a volcano, and to the solid rock

Fig. 94. Recent flow of lava from Kilauea, Hawaii. (U. S. Forest Service.)

which results from its cooling (Fig. 94). Most of the solid materials blown out of a volcano are pieces of lava which became solid before they were shot out, or during their flight in the air. They include masses of rock tons in weight, and smaller pieces of all sizes down to particles of dust (commonly called *volcanic ash*). The dust in many cases is shot high into the air, and, being light, is scattered broadcast by the winds, some of it coming to rest thousands of miles away. The liquid lava and the larger solid pieces, on the other hand, stay near the vent.

The gases and vapors which issue from volcanoes are of many kinds. Some are poisonous, and some are so hot as to be destructive to life, as in the case of Mont Pelée, in 1902 (p. 197).

Soils made by the decay of volcanic materials may be very fertile if well watered. The volcanic soils of the Spice Islands (Moluccas), Java, and other islands of the East Indies, support a luxuriant vegetation.

Number. The number of active volcanoes is not known, but is estimated at 300 to 400. Something like two-thirds of them are on islands, and the rest on the continents.

Distribution. The distribution of active volcanoes is shown in Fig. 95. Many are in belts, within which some are in lines. The

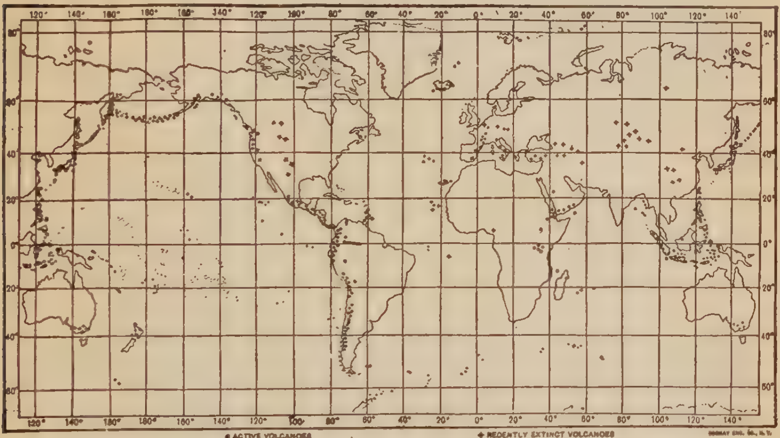


Fig. 95. Map showing the distribution of volcanoes. (Russell.)

most marked belt nearly encircles the Pacific Ocean. The volcanoes of the West Indies and of Java and Sumatra sometimes are considered as forming branches of the main belt. Outside this belt, there are a number of volcanoes in and about the Mediterranean Sea, and there are others which are not connected with any well-marked system.

Most volcanoes are in the sea or near it. Many are in mountain regions, though they do not occur in all mountains. Many of the active volcanoes are near the line where the continental plateaus descend to the ocean basins. Many volcanoes are in lands which have been raised or lowered recently.

Topographic effects of volcanoes. Some volcanic cones are mountains of great size, like Mt. Rainier (Tacoma) in Washington,

Mt. Hood in Oregon (Fig. 96), Mt. Shasta in California, and Orizaba in Mexico. All those named are so high that glaciers are found on their slopes. Volcanic cones are far more numerous than volcanoes, for the cones of many extinct volcanoes still remain.

Fig. 96. Mt. Hood, a snow-capped mountain.

Many small islands and some large ones are due chiefly or wholly to the building of volcanic cones on the ocean-bottom. The Aleutian Islands and the Hawaiian Islands were formed in this way. Iceland, too, is largely volcanic.

Destruction of volcanic cones. Volcanic mountains, like all other elevations on the land, are subject to change and destruction.

Fig. 97. Portion of Crater Lake, Oregon. (Copyright by Kiser Photo Co.)

They may be destroyed partially *by violent explosions*. Again, the top of a volcanic mountain may sink, leaving a great hollow, or *caldera*. Crater Lake, Oregon (Fig. 97), the deepest lake in North America, is in a caldera five or six miles in diameter, and 4,000 feet deep. The lake is surrounded by steep walls 900 to 2,200 feet high. Since the sinking of the top, a small cone, now an island in the lake, has been built.

Fig. 98. Typical cinder cone, Clayton Valley, California.

Volcanic cones are destroyed also *by the slow processes of weathering and erosion* (p. 306). Wind and rain attack them as soon as they are formed, but the results are not striking until the volcano is extinct and the cone stops growing. The many cones of extinct volcanoes in western United States are in various stages of destruction. Some in Arizona, California (Fig. 98),

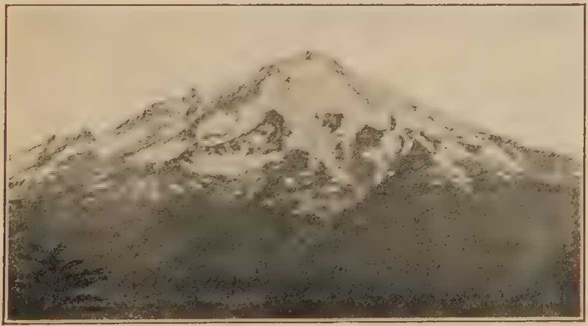


Fig. 99. Mt. Shasta, a typical volcanic cone furrowed by erosion, but retaining its general form. (U. S. Geol. Surv.)

Idaho, and Oregon were formed so recently that they have been eroded but little. Fig. 99 shows a high mountain built by a former volcano. It still retains its conical form, but its steep upper slopes are cut by ravines and valleys, several of which contain glaciers.

Destructiveness. Like earthquakes, some volcanoes have destroyed great numbers of lives and much property. During an eruption of Vesuvius in 79 A. D., Pompeii, a city of about 20,000 people,

Fig. 100. The ruins of Pompeii. (Doseff.)

was buried by cinders and ashes (Fig. 100), and Herculaneum was overwhelmed by streams of hot mud. Some of the later eruptions of this volcano also have been very destructive. That of 1631

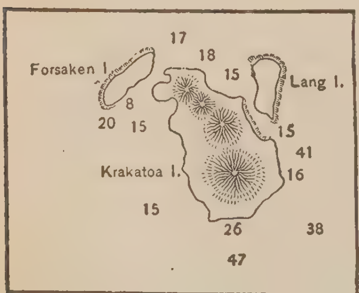


Fig. 101

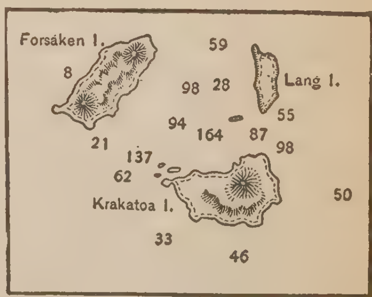


Fig. 102.

Fig. 101. Krakatoa Island and surroundings before the eruption of 1883.

Fig. 102. Krakatoa Island and surroundings after the eruption of 1883. The numbers indicate the depth of the water in fathoms (a fathom = 6 feet) in both figures.

destroyed some 18,000 lives. One of the most violent and destructive volcanic eruptions known was that of 1883 in Krakatoa, an island between Sumatra and Java. About two-thirds of the island was

blown away, and the sea is now nearly 1,000 feet deep where the center of the mountain formerly was (Figs. 101 and 102). Sea waves spread to Cape Horn, and possibly to the English Channel. On the shores of neighboring islands the water rose 50 feet. More than 36,000 persons perished, mostly by drowning, and 295 villages were destroyed, wholly or partially.

tidal

The volcano of Pelée is on the island of Martinique, at the eastern edge of the Caribbean Sea. Its cone descends by steep slopes to the sea on all sides but the south, where there is a plain on which the city of St. Pierre formerly stood. After slumbering for more than fifty years, the volcano became active in the spring of 1902. On May 8th a heavy black cloud, probably composed of steam, sulphurous vapors, and dust, which had an estimated temperature of 1,400° to 1,500° F., swept down through a gash in the crater's rim, and out over the plain to the southwest. In two minutes it struck the city of St. Pierre, five miles distant, which was demolished at once (Fig. 103). Buildings were thrown down, statues hurled to the ground, and trees torn up. Explosions were heard in the city as the cloud reached it, and flames burst out, started either by the heat of the gases, or by the red-hot particles of rock which the gases carried. A few minutes later a deluge of rain, mud, and stones fell, continuing the destruction. Only two people out of 30,000 survived the disaster.

Fig. 103. The ruins of St. Pierre, Martinique. (Hovey.)

Igneous Phenomena Not Strictly Volcanic

Fissure eruptions. Lava sometimes rises to the surface through great cracks instead of through the rather small vents of volcanoes. From such cracks floods of lava may spread over the land for hundreds of miles. Many such lava floods once occurred in Oregon, Washington, and Idaho, where the former hills and

valleys were buried, and a vast plateau 200,000 square miles or more in extent was built up (Fig. 104). In this lava plateau, the Snake River has cut a great canyon 4,000 feet deep in some places, and 15 miles wide. The walls of the canyon show that in some cases successive beds of lava are separated by layers of soil in which the roots and trunks of trees are preserved.

Fig. 104. Lava flows of the Northwest.

An older and larger lava plateau, more dissected by erosion, occurs in central and southern India. Still others, now made rough by erosion, are found in northern Ireland and western Scotland. Some of the islands off Scotland are remnants of an old lava plateau.

Intrusions of lava. Most of the lava forced upward from great depths probably fails to reach the surface, and hardens underground. Such rocks may be exposed at the surface through the wearing away of the rocks which overlay them. Great masses of intruded lava may bulge up the overlying strata, making domes (Fig. 105), some of which reach the size of mountains. The Henry Mountains of Utah are examples. In places, lava has been forced in between beds of rock, and into cracks in them (Fig. 106).

Fig. 105. Diagram of a *laccolith*.

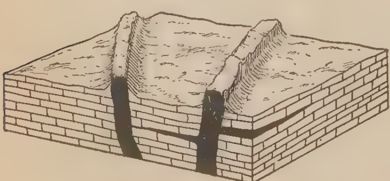


Fig. 106. Diagram showing lava which has been forced in between beds of rock (forming *sills*), and into cracks (forming *dikes*). What changes have occurred since the dike-rock was intruded?

Intrusions of lava may give rise to topographic features of importance after erosion has affected the regions where they occur, for the hardened lava is in many cases harder than its

surroundings. Many dikes form ridges. Intruded sheets of lava, if they have been tilted from a horizontal position, may also form ridges, and these ridges may be so high as to be called mountains. The Palisade Ridge of the Hudson (Fig. 107), and most of the mountains

Fig. 107. The face of the Palisade Ridge, west of the lower Hudson River.

of the Connecticut Valley, are examples. The steep ridges so important in the battle of Gettysburg are smaller examples of the same sort.

Causes of Vulcanism

The causes of vulcanism are not well known. How the liquid rock is formed, the depth of its source, and how it makes its way toward the surface, are unsolved questions. The old notion that volcanic vents are connected with a liquid interior has been abandoned.

It seems probable (1) that lava is being formed all the time, in spots, in the deep interior, and (2) that it is all the time finding its way toward the surface, but faster and in greater amounts at some times than at others. The places where the crust is weakest, that is, where there is movement, are the places most likely to afford the lava a place of escape.

Questions

1. At the west end of the island of Crete, in the Mediterranean Sea, old docks, near sea-level when built, are found many feet above the water. At the east end of the island, ancient buildings are under water. Was the change in the relation of land and sea thus recorded due to movement of the sea surface, or of the land? Why could it not have been due to the other?

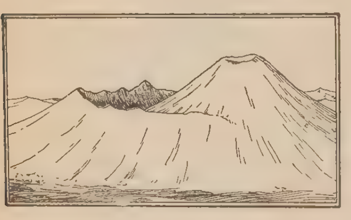


Fig. 108.

2. How would the coast-line of North America be changed if the bottom of the Indian Ocean were to sink enough to lower the surface of that sea 200 feet?

3. Other things being equal, which are more enduring, volcanic cones built of lava or of cinders? Why?

4. Will soil form quickly or slowly on the recent (1902) volcanic deposits of Martinique and St. Vincent? Why?

5. (1) What was the origin of the mountain in the right hand foreground of Fig. 108? The evidence? (2) Has much or little time elapsed since its formation? How told? (3) What is the probable history of the curving ridge at the left?

CHAPTER XV

MODIFICATION OF LAND SURFACES BY EXTERNAL AGENTS

The surface of the land is being changed all the time by various agents, especially by wind, by water in the ground, by running water, by ice, and in minor ways by different forms of life.

The Work of the Wind

Winds change land surfaces by taking dust and sand from certain places and depositing them in others. Wind-driven dust and sand may wear exposed surfaces of rock.

Transportation. Desert winds often sweep up "clouds" of dust which may be seen for miles, and a single storm may move millions of tons of dust and sand. The dreaded *simoon* of the Sahara has been known to destroy entire caravans, death resulting from suffocation in the dust-laden air. While transportation by the wind is most important in arid regions, it is not confined to them. Dry sand and dust are blown about wherever they are exposed to the wind.

Particles of dust are much heavier than air, and gravity tends to bring them down. Yet they may remain in the air for a long time (1) because they are so small that they do not fall readily, and (2) because there are many upward currents in the air which carry them up in spite of gravity. As a matter of fact, the dust of the air always is settling, and the supply is being renewed all the time. Dust in the air may be carried great distances. A severe storm in March, 1901, carried dust northward from the Sahara as far as Denmark. In 1883, volcanic dust from Krakatoa (p. 196) was carried around the earth by the upper winds in about two weeks, its progress being shown by the brilliant sunsets to which it gave rise.

Abrasion. Sand blown against a rock has the effect of a sand-blast, and wears the rock away. Abundant wind-blown sand, driven

against projecting rocks, may carve them into fantastic forms (Fig. 109). This process is of much importance in dry regions where the land is rough. In deserts and along sea coasts, telegraph poles have been cut off near the ground by wind-blown sand. In some such places, stones are piled about the bases of the poles to protect them (Fig. 110).

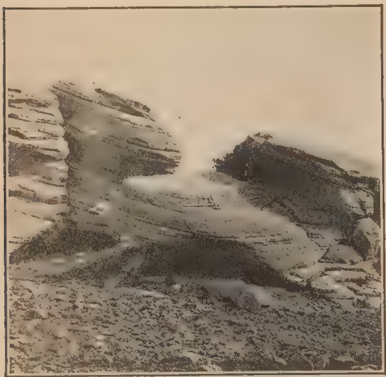


Fig. 109. Rocks carved by the wind. (Bastin.) What inferences may be made concerning the character of the rocks?

Wind deposits. Wind deposits of sand and loess have been described (p. 165). Sand usually is blown along within a few feet of the ground, and is therefore likely to lodge about any obstacle which blocks its way. Mounds, hills, and ridges of wind-deposited sand are *dunes*, which range in height from a few feet to more than 400 feet. Small dunes are much more common than large ones. Dunes are found mostly near the sources of abundant dry sand. They are common along much of the Atlantic coast of the United States, where sand is washed up on the beach by waves. After drying, it is blown about by the wind. Winds from the west blow this sand into the sea, but those from other directions, especially from the east, drift it up on the land. Dunes abound over thousands of square miles in the drier parts of the Great Plains, as in western Nebraska and western Kansas. They are largest and most numerous in still drier regions, as the Sahara. In some places, dunes are the most striking feature of the landscape.

Fig. 110. Telegraph pole in southern California, deeply cut by wind-driven sand. (Mendenhall, U. S. Geol. Surv.)

Sand is blown from the windward side of a dune and dropped on the leeward side, much of the time. This continued shifting of sand to the leeward side results in a slow migration of the dune. Farm lands have been covered in this way, and forests have been

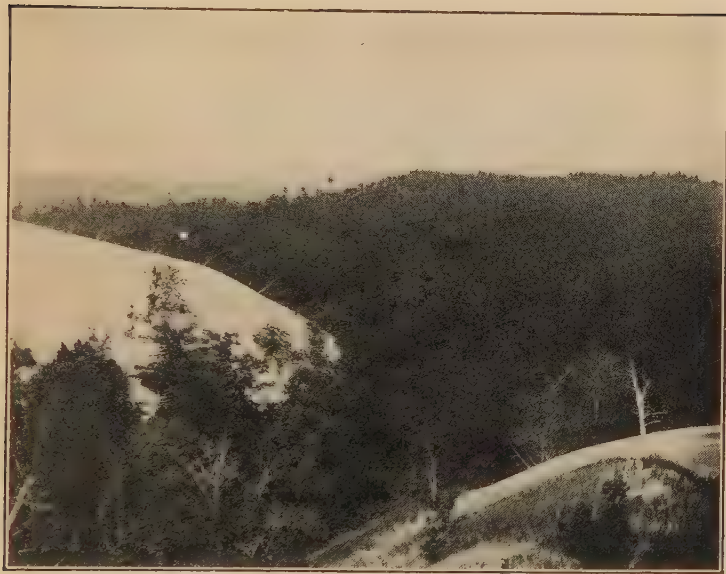


Fig. 111. Dunes advancing on a forest. Little Point Sable, Michigan.

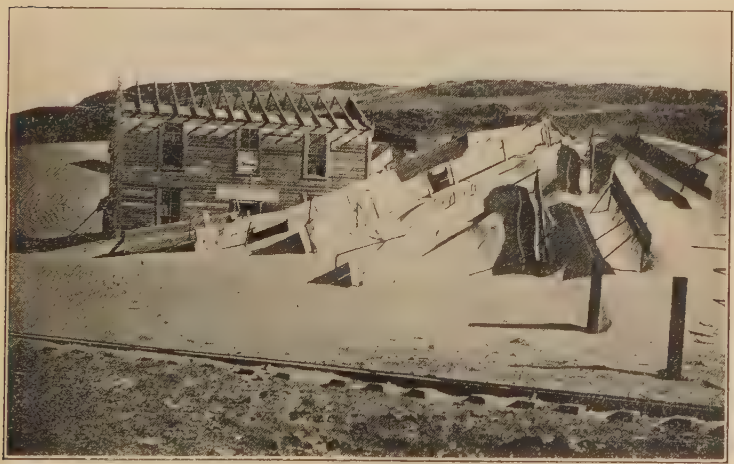


Fig. 112. Biggs, Ore., in 1899. The site of the former village was covered by dunes, and the last house was being torn down. (Gilbert, U. S. Geol. Surv.)

buried (Fig. 111). In some places sand buries buildings (Fig. 112), and causes much trouble along railways. The migration of dunes along some coasts is so disastrous that steps are taken to stop it. If a dune is covered with vegetation, its position is not likely to change so long as the plants remain, for they hold the sand. Trees, shrubs, and grasses which will grow in sand sometimes are planted on dunes to prevent further drifting (Fig. 113). This has been done at various points on the western coast of Europe, and to some extent in our

Fig. 113. Sand dune reclamation. Manistee County, Michigan. (Sketch from photograph by Forest Service.)

own country, as at San Francisco, where the westerly winds drift sand in from the shore. The amount of wind-blown sand not heaped up in dunes is probably far greater than that in dunes.

Summary. The more important phases of the work of the atmosphere may be summarized here. (1) Of most importance is its work as an agent of weathering (pp. 161–164). Through its effect on changes in temperature it helps to break rocks, and by the chemical action of its oxygen, carbon dioxide, and water vapor, it causes rocks to decay. Weathering prepares materials for removal by various agents of transportation. (2) The wind transports and deposits large amounts of fine material. Although most extensive in arid regions, this work has affected all land surfaces. Since the wind deposits much dust and sand in the sea, the general effect is to lower the lands and build up the ocean-bottoms. (3) Rocks are worn by wind-driven sand. This is most important in deserts, where the atmosphere is, in many places, the chief agent in wearing down the land. (4) By controlling the conditions of evaporation and pre-

cipitation, the atmosphere makes possible the work of streams and of glaciers, and the existence of land life.

QUESTIONS

1. Why are there many dunes on the eastern side of Lake Michigan, and but few on the western?
2. In most dune areas there are many hollows among the sand hills. In what ways are such hollows formed?
3. Why are dunes formed along some river valleys and not along others?
4. What changes in natural conditions may stop dune-building in a given region?

GROUND-WATER

GENERAL CONSIDERATIONS

The fate of rain-water. The average annual rainfall of the United States is about thirty inches. This means that a total of about 1,500 cubic miles of water (enough to cover New England to a depth of about 1,000 feet) fall as rain or snow in this country each year. It is thought that about half of this water evaporates, that about one-third of it runs off over the surface, and that the remaining one-sixth is taken up by plants or sinks into the ground.

The ground-water surface. It is possible almost anywhere to dig wells deep enough so that they will contain water all the time. This means that the surrounding rocks are full of water below the level of the water in the wells. The surface below which the ground is full of water in any given region is the *water surface* or *water table* for that region. In swamps and marshes the water table is at or near the surface of the ground, while in arid regions it may be hundreds of feet below. In humid regions it is seldom more than 50 or 60 feet below the surface. The position of the water table also varies from time to time. It is higher after heavy rains, and lower during and after long droughts.

Amount of water underground. The pores and openings in the rocks below the water surface are full of water. Some porous rocks contain one-third or more of their volume of water; very compact rocks contain but little. In general, rocks near the surface have more and larger pores and cracks than those at greater depths. Pores and cracks become very small at the depth of a few thousand feet, and probably none exist below a depth of five or six miles. If this is true, water does not descend to greater depths. There is water

enough underground so that, if it were brought to the surface, it would form a layer probably 500 to 1,000 feet deep.

Circulation of ground-water. Ground-water is moving all the time. This is shown, for example, by the constant flow of springs, and by the fact that after a well is pumped "dry," it soon fills again to the former level, because water seeps in from the surrounding rocks. Ground-water moves because the water table is not level everywhere, and the water moves from places where its surface is higher to places where it is lower. The water table is kept uneven, partly

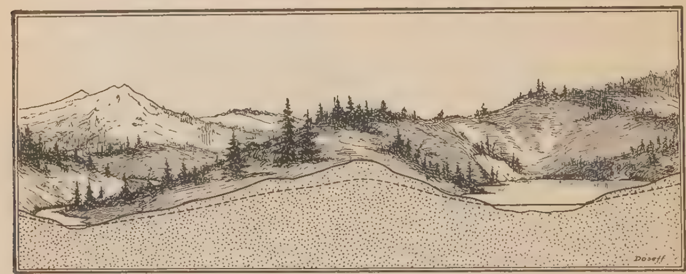


Fig. 114. Diagram showing the relation of the level of ground-water (the broken line) to the surface of the ground and to a lake and river.

because of unequal rainfall, and partly because of the uneven surface of the land. Other things being equal, the water table is higher beneath high land, and lower beneath low land (Fig. 114). The water surface below the high land tends to sink until it is as low as that beneath the low land; but in moist climates it rains so often that the water surface under the hills almost never sinks to the level of the water in the surrounding low lands, before it is raised again by rains.

Water which sinks to great depths commonly follows an irregular course. At first its movement is chiefly downward, and is rather rapid because of the many large cracks and pores in the rocks near the surface. Farther down, its movement is largely sideways (Why?). It may flow slowly for many miles along a crooked course, through small openings, before it reaches a passageway leading to the surface. Through such an opening it may issue with great force as a spring or flowing well. Fig. 115 suggests the intricate circulation of the water which issues in a deep-seated spring. Some water flows underground to the sea or to lakes, and issues as springs beneath them. Much

ground-water, too, seeps out in such small amounts that it does not appear to flow, and does not make a spring.

Much ground-water is taken up by roots, passes up through the plants, and comes out through their leaves (is *transpired*) into the air. The amount of water returned to the air daily by forests through their foliage varies under different conditions from 1,000 to 20,000 or more pounds per acre, during the growing season. About 5,000 pounds of water are transpired by the foliage of corn-plants in the production of a bushel of corn. Again, water is evaporating from the ground most of the time, even in regions where the soil appears to be very dry.

Fig. 115. Diagram showing the intricate underground drainage which issues in a deep-seated spring. (Geikie.)

The rate at which ground-water moves depends chiefly on (1) the porosity of the rock or soil, and (2) the pressure of the water. The rate at which water seeps through soils from irrigating ditches in the West is in most cases from one to eight feet per day; but in very porous soils it is sometimes 50 feet per day. In widespread beds of sandstone which underlie southern Wisconsin and northern Illinois, the rate of movement of ground-water is about half a mile a year. At this rate, rain-water which enters these beds 100 miles from Chicago would reach that city in about 200 years.

Knowledge of the circulation of the upper part of the ground-water is important to every family using well-water for household purposes. Polluted well-water is very common on farms which might have pure and wholesome water. Great numbers of wells are so situated that ground-water moves toward them from cess-pools and stables. Largely as a result of this, typhoid fever is more common in many farming regions than in most cities.

Uses and functions of ground-water. Ground-water is of vital importance in the economy of the earth and in human affairs. (1) It is important to plants. It dissolves the mineral elements of plant food and carries them to the roots. The amount of water available for plants is the most important factor conditioning their life in many regions. (2) Underground water supplies all springs and wells, the sources from which perhaps three-fourths of the people of the United States obtain their water for household use.

The distribution of population in eastern United States was influenced greatly by running water and natural springs, until modern methods of well-digging were developed. Absence of springs, and the use for two years of the brackish water of the James River, were one cause of the high death-rate in the Jamestown colony. A supply of wholesome water helped to determine the location of the Pilgrim colony at Plymouth, and of the Puritan settlement at Boston. Many of the stockaded villages of the early western frontier were so located as to command a supply of water in the event of an Indian siege. The settlement of certain inter-stream areas in southern Wisconsin and in Illinois was delayed for years, partly because of the difficulty and expense of digging wells. In the arid West, springs and watering places determine the location of many villages and farms, and influence the course of trails and roads (Fig. 116). Their location is shown on many maps for the benefit of travelers.

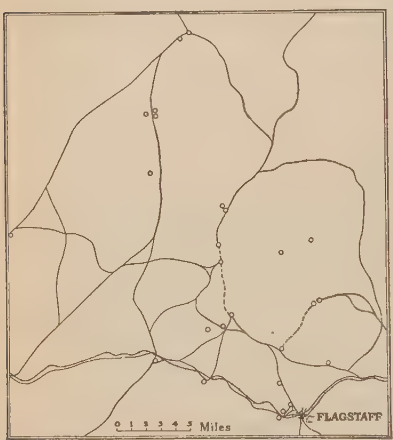


Fig. 116. Map showing springs (by circles) and roads in the region of Flagstaff, Arizona. (From San Francisco Mountain Sheet, U. S. Geol. Surv.)

Because of the importance of ground-water to plant, animal, and human life, it is highly desirable that the water table be kept near the surface of the ground. It is estimated that in eastern United States it has been lowered from 10 to 40 feet over large areas by cutting off forests and by careless methods of tillage which have increased the proportion of the rain-water that runs off over the surface. It is estimated that at least three-fourths of the shallow wells and springs have failed in this part of the country. (3) Ground-waters bring about important changes in the character of the rocks through which they pass. These changes take place slowly, but they are going on all the time.

OUTFLOWING WATERS

Hillside and fissure springs. Fig. 117 illustrates two kinds of springs. In the one, water descends through a porous bed of rock, *c*, to a layer, *a*, which is compact. Much of the water flows along this layer until the latter comes to the surface (*out-crops*), and there the water issues as a *hillside spring*, *s*. The great majority of springs are of this class, and most of them are small. In the other

case (Fig. 117), the water moves through the porous layer, *b*, under pressure, until it reaches a crack which leads up to the surface. If the crack is open, the water will follow it up to the surface, as at *s′*, forming a *fissure spring*. In such a situation there will be a spring only when the opening is lower than the water surface in the layer

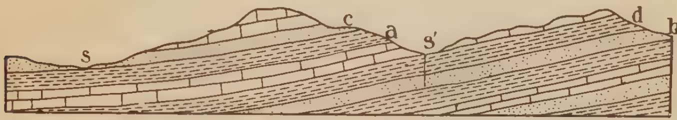


Fig. 117. Diagram to illustrate two types of springs, as explained in text.

of rock which carries the water. This sort of spring is similar to a flowing well in principle, though in the latter case the opening is made by man.

Artesian wells. Formerly, artesian wells were regarded as the same as flowing wells. Now, the name "artesian" often is applied to deep, drilled wells, whether they flow or not. Fig. 118 illustrates

Fig. 118. Diagram illustrating the conditions necessary for flowing wells

the conditions necessary for flowing wells. They are: (1) A porous layer or bed of rock, *A*, under one which is not porous, and which prevents the water from escaping upward until it is penetrated by the well hole, *W*. The porous bed must come to the surface in a region which is higher than the site of the well; and (2) enough rainfall where the porous bed comes to the surface to keep that bed well filled with

water. Under these conditions, the water will gush up (Fig. 119), if a hole is made down to it.

Flowing wells may be but a few feet deep, or they may be thousands of feet deep. Thus there is one in St. Louis nearly 4,000 feet deep, and many in New Jersey less than 100 feet in depth. Many villages and small cities get their water from artesian wells; but great cities, such as New York and Chicago, could not get enough in this way. Brooklyn obtains a part of its supply in this way, its artesian wells furnishing about 22,000,000 gallons per day. In parts of the West, artesian waters are used extensively for irrigation, as well as for domestic and other purposes.

Fig. 119. An artesian well at Lynch, Nebraska. Flows more than 3,000 gallons per minute. (Darton, U. S. Geol. Surv.)

In some regions more wells have been drilled than are needed, and when not in use (in many cases this is the greater part of the time) the water from the flowing wells has been allowed to run off freely. This has reduced so greatly the pressure and the amount of water available, that villages and cities, formerly abundantly supplied from artesian wells, have been compelled to seek other sources of supply. This is the case, for example, in some parts of the Dakotas. In some of the arid states where the water problem is critical, as in California, strict laws exist to prevent the waste of artesian and other underground waters.

Geysers. Geysers are hot springs which erupt from time to time (Fig. 120). So far as known, they occur only in a few regions of recent volcanic activity — Yellowstone National Park, New Zealand, and Iceland. From a few geysers water is thrown to a height of 200 feet or more, by steam produced at some point in the geyser tube below the top of the water. It is believed that hot volcanic rocks make the water boil, and the expansion of the steam formed causes the eruptions. (How will the cooling of the rocks affect the frequency of eruptions? What will be the final fate of existing geysers?) Although interesting, geysers are of little importance.

Other hot springs. Some springs are warm, and others are hot. Where spring-water is hot, it is in some cases because it has been in contact with lava which came up from greater depths so recently that it has not yet become cold. In other cases the heat may be due to chemical changes taking place beneath the surface. There are more than 3,000 hot springs in the Yellowstone National Park, and many others in different parts of the country.

Mineral and medicinal springs. All spring-water has some mineral matter in solution; but a spring is not commonly called a *mineral spring* unless it contains (1) much mineral matter, (2) mineral matter which is unusual in spring-water, or (3) mineral matter which is conspicuous either because of its color, odor, or taste. Many mineral springs are thought — and some rightly — to have healing properties, and so are known as *medicinal springs*. Many of the famous watering-places and resorts for invalids are at hot mineral springs. The Hot Springs of Arkansas, Virginia, South Dakota, and Carlsbad (Bohemia) are examples. Many springs which are charged with gases are called mineral and medicinal, even though their waters are worthless for healing purposes. In 1911 mineral water was sold from about 700 springs in the United States. The amount of water sold was more than 67,000,000 gallons, valued at about $7,800,000.

Fig. 120. The Wairoa Geyser, New Zealand. Shoots 1,500 feet. (New Zealand Gov't Tourist Dept.)

WORK OF GROUND-WATER

Solution. All water which comes out of the ground has in solution some mineral matter dissolved from the rock through which the water has passed. Pure water does not dissolve mineral matter readily; but rain-water is not pure, for it dissolves gases from the air, and in sinking through the soil takes up the products of plant decay. With these impurities in solution, ground-water dissolves most sorts of mineral matter more readily than pure water would. The amount of mineral matter brought to the surface through springs is very great.

Much ground-water finds its way to rivers after it seeps out. The larger part of the mineral matter in solution in rivers has come from ground-water which has flowed to them. All the rivers of the

earth are estimated to carry nearly five billion tons of mineral matter to the sea in solution each year. The transfer of so much mineral matter in solution from land to sea, lowers the land.

Some of the mineral matter carried to the sea in this way remains in the sea-water. Thus, most of the salt which has been carried to the sea remains there, probably, to this day. On the other hand, much of the mineral matter taken to the sea is used by sea animals (and some plants) for making their shells and bones, and these are left on the sea-bottom when the organisms die.

Caverns and cavern life. By the dissolving work of ground-water, rock is made porous. Small pores and cavities are more numerous than large ones, but some of the openings made in this way, such as Mammoth Cave in Kentucky and Wyandotte Cave in southern Indiana, are very large. Such caves occur chiefly in limestone, for this is the most soluble of the common rocks.

A few animals live in caves and some of them show peculiar features. They are colored less brightly than their relatives above ground. This is probably because of the absence of sunlight, which seems to have much to do with producing color in animals. Some cave animals have good eyes, some have poor eyes, and some have none. From these and other facts, we infer that the eyes of animals in dark caves tend to disappear. The organs of touch are well developed in cavern animals. In the darkness the sense of touch is much more useful than sight.

In Europe, certain caverns were the homes of primitive man, as shown by the human bones and the tools which are found in them. Here, too, are found the bones of large animals which were killed for food or fur, and taken to the caves. On some of the bones of such animals, and on pieces of slate or wood, there are drawings, some of which are of animals no longer living in the region where the caves are. From this we infer that the people who lived in the caves dwelt there a long time ago.

Deposition. Ground-water sometimes leaves a part of its dissolved mineral matter in the pores and cracks of the rocks through which it flows. When cracks in the rocks are filled or partly filled by mineral matter deposited from solution, the fillings become *veins* (Fig. 121). Many ores of gold, silver, lead, zinc, copper, and other metals, occur in veins. Originally, most of the metals were scattered widely through the rocks. They were dissolved, and then deposited by ground-waters in the cracks and openings where they are now found. Thus ground-water has made the great deposits of most ores, so important to mankind (pp. 179–182). Ground-waters also deposit mineral matter among particles of loose sediment, cementing them into firm rock.

Mineral matter brought to the surface by ground-water may

be deposited there, as the result of various causes. (1) When water evaporates, the mineral matter dissolved in it is left behind. This is one reason why kettles in which water is boiled become coated with mineral matter. (2) Certain gases dissolved in water help it to dissolve mineral matter. If water contains much gas, which later escapes, as when the water is heated, some of the mineral matter in solution may be deposited. (3) Warm spring-water may give up what it holds in solution when it cools. (4) Microscopic plants grow in the waters which issue from some hot springs, as in Yellowstone Park, and by some process not well understood extract mineral matter from the water, and cause it to be deposited.

Fig. 121. A quartz vein (the white band) filling a crack in much older rock. Muchals Caves, Kincardineshire, Scotland.

Solution and deposition may be going on at the same time, in the same place. Thus the original material of a buried shell may be dissolved and carried away at the same time that other material is left in its place, preserving the form of the shell. In the same way, wood may be replaced by mineral matter, giving rise to *petrified wood*, or wood "turned to stone." Such changes probably take place slowly, the mineral matter which was in solution in the water replacing the woody matter as it decays.

Mechanical work. Mechanical wear by ground-water is slight, since ground-water rarely flows in strong streams. Indirectly, ground-water helps to bring about changes of another sort. When the soil on a steep slope becomes full of water, its weight is increased greatly, and the water in it makes it move more easily. Under these circumstances, it sometimes slides down. Such movements are known as *slumping or sliding*. If the slide is large, it usually is called a

landslide (Fig. 122). Slumping is very common on the slopes of hills composed of clay or other loose matter. Many landslides have been very destructive.

Fig. 122. A landslide. (Sketch from photograph by Hole.)

In 1903 there was a slide on Turtle Mountain, Province of Alberta, Canada. A huge mass of earth nearly half a mile square, and probably 400 to 500 feet deep, suddenly slid down the steep face of the mountain, into the valley below. The length of the slide was about two and a half miles, and it is estimated that the time which it took was not more than 100 seconds. The heavy rainfall of the preceding year had filled the rock with water, and the earth tremors which occurred shortly before the slide are believed to have hastened the catastrophe.

Fig. 123. A ravine near Crawfordsville, Indiana, showing trees leaning down-slope, in part because of creep. The surface material creeps faster than that below, tipping the trees toward the axis of the ravine.

Water in the soil and subsoil works with gravity in the extremely slow, down-slope movement of surface material. This sort of movement is *creep* (Fig. 123), which is usually too slow to be seen.

SUMMARY

From the preceding paragraphs it is apparent that the existence and work of ground-water are matters of great importance. (1) Without water in the soil most plants could not live, and the amount available largely controls both the density and the character of the vegetation. (2) Chiefly through its influence on plant life,

ground-water helps to determine the distribution and occupations of people. (3) Ground-water is the source of all wells and springs. Ground-water, seeping out, maintains the flow of most streams. (4) Ground-water may modify the character of rocks in several ways: (a) by removing soluble constituents; (b) by depositing new material in rock cavities; (c) by replacing old material with new; and (d) by favoring new chemical combinations. These changes must have occurred on a vast scale, for ground-waters have been at work for untold millions of years. As a result, soils and useful ores have been accumulated. (5) The mechanical work of ground-water is relatively unimportant, but widespread. The creeping and slumping of surface material are in some cases due partly to ground-water.

QUESTIONS

1. In order to contain water constantly, must wells extend farther below the surface of the ground on hill tops or in valley bottoms?

2. In order to increase the flow of water, dynamite is sometimes exploded in wells. Why does this in many cases produce the desired effect? Would it be more likely to succeed with wells in hard, brittle rocks, or soft, tough rocks?

3. Make a diagram showing (1) the surface of the ground in a hilly region containing a lake, a swamp, and a river, and (2) the position of the water table beneath this surface (a) after continued rains, and (b) during a long drought.

4. What effect does the irrigation of arid lands by water led in ditches from streams have on the position of the water table? How does this affect the question of the acreage which may be irrigated in years to come?

5. Why are the inscriptions on many old tombstones indistinct?

6. Describe the characteristics of a climate which should (1) hinder, and (2) favor solution by ground-water.

The Work of Streams

Running water is more effective than wind in changing the surface of the land over which it moves, largely because water is about 80 times heavier than air. The work of running water is also much more important than that of ice, because water moves more readily and affects larger areas. It is true that glaciers have been much more extensive than now at different times in the past, but this was the case, so far as known, only for comparatively short periods. On the other hand, streams are numerous in most lands, and have been for untold ages. All in all, running water is more important than all other agents in shaping the details of land surfaces.

Streams modify land surfaces (1) by moving loose material to

lower levels, much of it to the sea, (2) by wearing their channels, and (3) by depositing their excess loads in various forms. These phases of river work, together with their topographic results and some of their human relations, are discussed below. The use of streams, as for commerce, manufacturing, and irrigation, is discussed in Chapter XVI.

TRANSPORTATION

Gathering sediment. As rain-water flows down the slopes on which it falls, it carries particles of earth to the streams below. A stream gets much sediment in this way, if the immediate run-off flows over bare, steep slopes of loose material, and little, if it flows over slopes well covered with vegetation, such as grass land or forest. Besides the sediment brought to it by slope wash, a stream also gathers material from its bed and banks.

A stream is not a single, straightforward current. When water runs swiftly through an open ditch or gutter, some of it may be seen to move from sides to center, and some from center to sides, while eddies are common. There are also many subordinate currents in the main current of a river, and they move in various directions. Many of them are caused by the unevenness of the bed of the stream (Fig. 124). Some of them move upward and carry sediment up from the bottom of the stream.

Fig. 124. Diagram to illustrate the effect of irregularities, *a* and *b*, in a stream's bed, on the current striking them.

Ground-water dissolves rock slowly, and springs bring some of this dissolved matter to streams (p. 211). Most dissolved substances are invisible, and remain in the water even after it has become quiet. The amount of matter carried to the sea in solution each year by all rivers (p. 211) has been estimated to be about one-third as much as the sediment carried by them.

Carrying sediment. Coarse materials, such as pebbles, in most cases are rolled along the bottom, while fine materials, such as mud and silt, are likely to be carried in suspension. The behavior of the fine sediment in suspension needs explanation.

Mud consists chiefly of tiny particles of rock, nearly three times as heavy as water; hence they tend to sink all the time. But as

gravity brings them down, many are caught by upward currents (Fig. 124), and carried up in spite of gravity. *It is largely by means of these minor upward currents in the main stream, that sediment is kept in suspension.* Particles of sediment suspended in a stream are dropped and picked up repeatedly, and the long journey of any particle is made up of many short ones.

Amount of load. The amount of sediment a stream carries depends on (1) its swiftness, (2) its volume, and (3) the amount and kind of sediment which it can get. Swift and large streams can carry a heavier load than slow and small ones. The effect of velocity on the carrying power of streams may be seen in most creeks and rivers which are wider in some places than in others. Where the channel is narrow, the current is swift, and here, in many cases, all fine material has been swept away, leaving only pebbles and larger stones in the channel. Where the channel is wider, and the current slower, the bottom of the same stream may be covered with sand or mud. By narrowing the channel of the Mississippi by making jetties near one of its mouths, in 1875, James B. Eads not only prevented further deposition of sediment there, but forced the river to clear out its own channel. This change permitted larger ocean vessels to reach New Orleans.

The amount of material which certain streams carry to the sea has been estimated. For a given river, the estimate is made by calculating the average amount of water (in gallons or in cubic feet) discharged by it each year, and then determining the average amount of sediment in each gallon or each cubic foot. The Mississippi River carries to the Gulf of Mexico an average of more than a million tons of sediment a day. It would take nearly 900 daily trains of 50 cars, each car loaded with 25 tons, to carry an equal amount of sand and mud to the Gulf. This sediment represents a great loss to the country (p. 167), for most of it would make soil of great fertility, if it were on land. All the rivers of the earth are carrying perhaps 40 times as much as the Mississippi.

CORRASION

How streams wear rocks. As already stated (p. 216), streams wear (*corrade*) their channels. If the channel is muddy, the moving water picks up sediment; if sandy or gravelly, sediment is rolled along the bottom. Many streams flow on solid rocks, and they gather load even from them. Rock exposed to water, as in the bed of a stream, decays. As it decays, it crumbles, and the crumbled parts are swept away by a swift current. Again, the sand and gravel rolled along by a stream wear its bed even if it is of hard

rock. Subordinate currents sometimes drive the sediment in suspension against the bottom or sides of the channel with similar results. The bits of sediment which a stream carries therefore become tools (Fig. 125), with which even hard rock is worn away. Clear water, flowing over firm, hard rock, wears the rock little. This is shown

Fig. 125. The tools of a river. Stream-worn pebbles in the bed of the St Joe River, Washington. (Tolman.)

by the fact that in many cases even large rivers flowing from lakes have "mossy" channels. (Why do such rivers have few tools?)

Rate of erosion. The rate at which a stream wears down the surface over which it flows depends largely on (1) its *volume*, and this depends chiefly on the amount of precipitation, and on the size and topography of the area draining to it; (2) its *velocity*, which is determined chiefly by its slope, or *gradient*, and its volume; (3) the *character of its bed*, especially the resistance of its materials; and (4) the *load* which the running water carries. To work most effectively, the water must have tools enough to enable it to cut rapidly, but not so many that the energy expended in moving them retards its flow seriously. Since the factors named above vary greatly, the rate at which the land is being worn down is very unequal in different places. The average rate of wear for the United States is thought to be about 1 inch in 760 years; but the rate varies from

an average of 1 inch of reduction in about 440 years in the Colorado Basin, to 1 inch in about 3,900 years in the basin of the Red River of the North (Fig. 126).

FEATURES DEVELOPED BY STREAM EROSION

River Valleys

The depressions in which rivers flow are their *valleys*, and in the making of valleys streams have been the chief agents.

River valleys centers of human activity. Most of the great valley lowlands of middle latitudes are settled densely, because

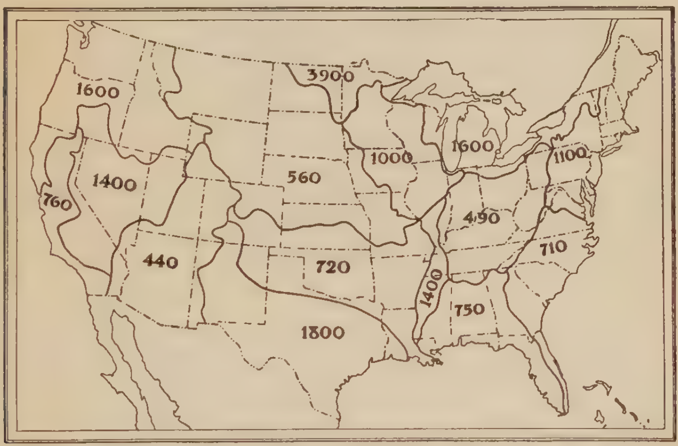


Fig. 126. Rates of land reduction by stream erosion in the United States. The figures are the approximate number of years required for one inch of reduction. (Dole and Stabler, U. S. Geol. Surv.)

of their fertile soils, favorable topography, and facilities for communication. Probably more than one-fourth of the people of eastern United States live on alluvial lands.

The valleys of the United States have been sought out for settlement from the beginning of its history. New York history began at the mouth of the Hudson, Pennsylvania history in the valley of the Delaware, and that of Virginia on the banks of the James. Later, various valleys became highways of expansion toward the interior. The overflow from the settlements of the coastal lowlands of Massachusetts passed over the rocky and infertile uplands

to the west, to the inviting bottom lands and terraces of the Connecticut Valley. As years passed, this great valley led settlers northward into New Hampshire and Vermont. The Ohio Valley was one of the first sections of the interior to be settled, and for many years the Ohio River was a main highway of westward expansion. The upper Rio Grande Valley guided settlers northward from Mexico into the United States. The Platte Valley directed many fur traders and trappers across the Great Plains; it was followed by the Mormons on their way to Utah; along it ran the Oregon Trail and the first trans-continental railroad; and it was the greatest gateway into Nebraska when, in the fifties, the latter began to be settled. Many other examples of the part which valleys have played in expansion and settlement might be given.

Fig. 127. A gully made by a single shower.

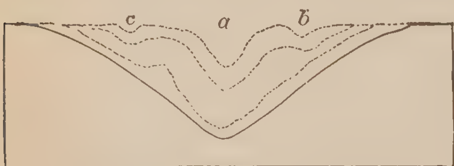


Fig. 128. Diagram illustrating how one gully takes others as a result of growth.

The larger rivers of eastern United States were long the great highways of trade and travel. Much of the Interior depended largely on the Mississippi and its tributaries as outlets to market, before the building of railroads (p. 274). In the future, the larger rivers of the United States probably will be used more than now for transportation (p. 287).

Many valleys are grown-up gullies. Many valleys are enlarged gullies. A gully started during one shower (Fig. 127) is made

deeper, wider, and longer by the next. As the result of repeated showers year after year and, in many places, repeated meltings

Fig. 129. Gullying in southwestern Iowa. (Iowa State Drainage, Waterways, and Conservation Commission.)

of snows, the gully grows to be a ravine, and later a valley. Not all gullies, however, become valleys. Many gullies may start on one slope, but as they grow, some are so widened as to take in others (Fig. 128), and the number is reduced. Few gullies become ravines, fewer still become small valleys, and the number of valleys which attain great length is very small.

Fig. 130. Brush dams built to check erosion in the southern Appalachians.

Growth of gullies should be prevented. Much land in the United States has been ruined and much more injured, by gullies. There are many examples of such land in the southern Appalachians, where, on bare surfaces, gullies form and grow rapidly because the slopes are steep,

the rainfall heavy, and much of the surface material is eroded easily. Surfaces of this sort should, as a rule, be given over to the growth of forests. But serious gullying is by no means confined to mountain areas (Fig. 129), and the problem of checking the growth of gullies is country-wide. One of the best ways of stopping their growth is by filling them with brush (Fig. 130).

How valleys get streams. Water commonly flows in gullies only when it rains or when snow melts, and for a short time afterward. But many valleys made from gullies have permanent streams, so that they are being made larger all the time.

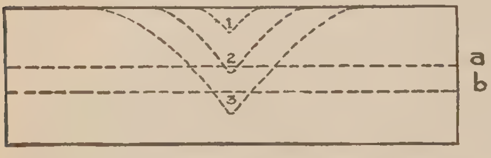


Fig. 131. Diagram showing ground-water surface; *a*, the ground-water surface in wet weather, and *b*, in times of drought. When a valley has been cut below *a*, there will be a stream in wet weather, but it will go dry in time of drought. When the valley bottom is below *b*, the stream will be permanent.

When a valley has been deepened so that its bottom is below the ground-water surface, ground-water seeps or flows into it, and forms a stream. In Fig. 131, *a* represents the water surface in wet weather, and *b* the water surface in dry weather. The valley whose cross-section is shown by 1 does not have a stream fed by ground-water; the valley 2 has a small stream in wet weather; while the valley 3 has a permanent stream, because its bottom is below the ground-water level of dry times.

Streams which are fed by lakes, and streams which flow from snow- and ice-fields which last from year to year, do not depend on ground-water, though in most cases they receive it.

The deepening of valleys. Swift streams remove material from their beds and so make their valleys deeper, but many slow streams deposit more sediment than they take away, and so make their valleys shallower. Many streams deepen their valleys in their upper courses where their waters are swift, while they make them shallower in their lower courses where the flow is sluggish. As a stream deepens its valley, the gradient becomes less, and the stream flows more and more slowly. In time, every swift stream will cut its channel down until its gradient is low and its current sluggish. A stream cuts the *lower end* of its channel down to about the level of the lake, sea, or river into which it flows, but the channel rises from its lower end to

its head. The lowest level to which a stream can reduce its basin is *base-level.*

The widening of valleys. Valleys are widened in many ways, among them the following: (1) A stream may flow against one side of its channel with such force as to undercut the slope above. Slow streams are more likely to widen their valleys in this way than swift ones, because they are turned more easily against their banks by obstacles in the channels. (2) Rain-water flowing down the slopes of a valley carries earthy material with it. This widens the valley, by slowly wearing back its slopes. (3) The loose matter which lies on the slopes of a valley creeps slowly downward, especially when wet. It may also *slump* down steep slopes. In these and other ways, all valleys are being widened all the time.

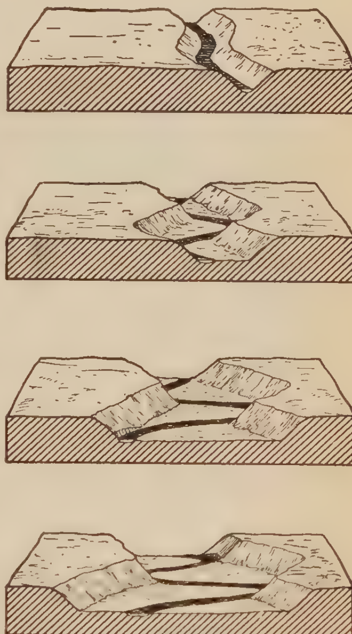


Fig. 132. Diagrams of a river making a flat by side cutting.

After streams have cut their valleys down to low gradients, they make flats in their bottoms, by side-cutting (Fig. 132). These flats are below the level of the surface in which the valleys lie, and may become very wide (Fig. 133). Thus the Mississippi River at Memphis has a flat about 35 miles wide. Most valley flats increase in width more or less regularly down stream (Why?).

The lengthening of valleys. The headward growth of a gully is due chiefly to erosion by the water which flows into its upper end. The head of a gully advances in the direction of greatest wear, and this is rarely in a straight line. Most valleys are therefore crooked from the outset.

The headward growth of a valley normally continues until the wear of the water flowing into its upper end is equaled by the wear

of the water flowing from the same *divide* (water-parting) in the opposite direction. The divide is then permanent (Fig. 134).

Valleys are not all grown-up gullies. Not all valleys were formed by the growth of gullies. A vast area in northern North

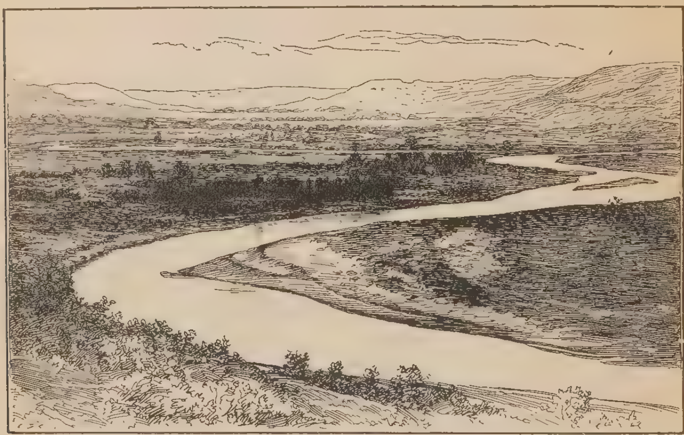


Fig. 133. A wide valley flat. Milk River, near the Montana-Alberta boundary. (From photograph by U. S. Geol. Surv.)

America, for example, once was covered by a sheet of snow and ice. Most of the rivers which had existed in this area ceased to flow while the ice lay on the land. Many of their valleys were filled, at least in places, by the drift which the ice left when it melted, and so great areas were left without well-defined valleys. The melting ice, however, supplied much water, and this flowed along the lowest lines of descent which it could reach, and made valleys along those lines. Valleys made by such waters may have permanent streams at the start, since they do not depend on ground-water.

Fig. 134. Diagram of a divide. The crest of the divide (at A) is permanent if the conditions of erosion are the same on the two sides. Rainfall may lower it, but cannot shift its position horizontally.

Again, the melting of the ice left many lakes in the hollows of the land it had covered, and the rainfall of the region was great enough to make many of them overflow. When a lake overflows,

the out-going water follows the lowest line of descent, and cuts out a valley. In these ways, rivers soon were formed on the surface from which the ice melted.

Valley and river systems. Most valleys are joined by many smaller valleys. The reason is simple. The erosion of the slopes of valleys by the water flowing from them to the valley-bottoms is greater along some lines than others (Why?), and tributary gullies are started, which, growing in the same way as the parent valleys, may come to have permanent streams. These tributary valleys of the first generation come to have branches, and the process may go on until a network of watercourses affects the surface.

A valley and its tributaries constitute a *valley system*. A stream and its branches form a *river system*, and the area drained by a river system is a *drainage basin*.

Stages in the history of valleys and streams. Valleys grow in size as they advance in years. When a valley is *young*, it is narrow and its slopes are steep. If the land is high, the valley may have a steep gradient, in which case it soon becomes deep. Its cross-section is then somewhat V-shaped (Fig. 135, 1), and its tributaries are short. A *mature valley* is wider (Fig. 135, 2), its slopes in most cases are gentler, and its tributaries are longer and older. An *old valley* is wide, and has a broad flat and a low gradient (Fig. 135, 3).

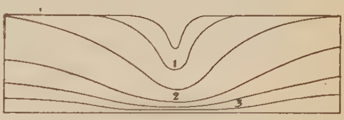


Fig. 135. Diagram showing changes in the shape of a valley as it advances from youth to old age. 1 = youth; 3 = old age. The material in which the valley is cut is all of the same character.

A stream also, as well as its valley, passes from youth to maturity, and from maturity to old age. In its youth, it is likely to be swift, unless it flows through low land. In maturity, it flows less swiftly and more steadily, and when it reaches old age, it winds slowly through its wide plain. Even an old stream, however, may take on the vigor of youth when in flood.

The terms *youth*, *maturity*, and *old age* may be applied to river systems as well as to single rivers. Every river system, aided by weathering, has entered on the task of carrying to the sea all the land of its basin which is above base-level. So long as the river system has the larger part of its task before it, it is *young*. When the main valleys have become wide and deep, and the areas of upland have been well cut up by valleys, the river system is said to have reached *maturity*.

When the task of reducing its drainage basin to base-level is nearing completion, the river system has reached *old age.*

The topography of a drainage basin is *youthful* when its river system is youthful, *mature* when its river system is mature, and

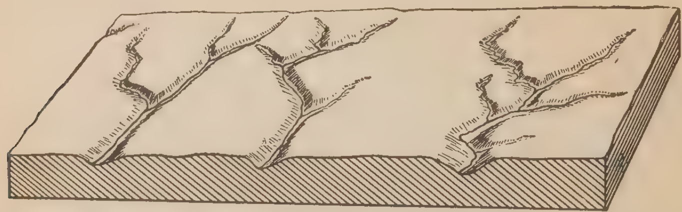


Fig. 136. Diagram of an area in a youthful stage of erosion. The area is some distance from the sea. The bottom of the diagram represents sea-level.

Fig. 137. Diagram showing mature topography in a region situated some distance from the sea. The bottom of the diagram is sea-level. The area shown in Fig. 136 will in time resemble closely the present appearance of this area.

Fig. 138. Diagram showing old topography in a region situated some distance from the sea. The bottom of the diagram is sea-level. Unless the land is elevated, the areas represented in the two preceding figures will finally closely resemble this area.

old when its drainage is old. In an area of *youthful topography*, much of the surface has not yet been much changed by erosion (Fig. 136), and the surface may be ill-drained. In an area of *mature topography*, much of the surface has been reduced to slopes by erosion

(Fig. 137), and is well-drained; while an area of *old topography* is one which has been brought down to general flatness by erosion (Fig. 138).

When an area is worn as low as running water can bring it, it is a *base-level plain*. As streams wear the land toward base-level, they flow on diminishing gradients. Because of this, their velocity and therefore their erosive power decrease constantly. In other words, an area approaches base-level more and more slowly the nearer it gets to it, and it may take as long to wear away the last few feet above base-level as it did all the other hundreds or thousands

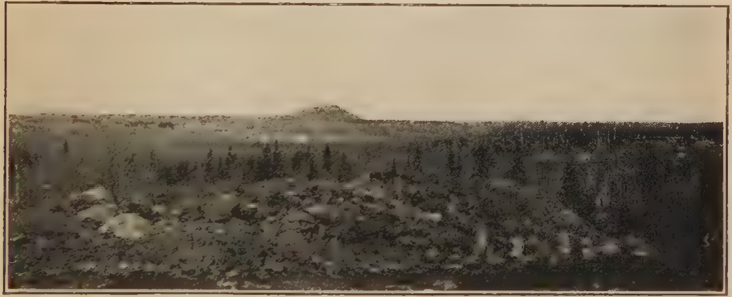


Fig. 139. A monadnock on a peneplain. Tower, Minnesota. (Mead.)

of feet that once lay above. Few, if any, areas have been absolutely base-leveled. The time required is enormous, and before the task is completed, an area is likely to be elevated with reference to sea-level, and the quickened rivers started upon the task of again reducing the elevated land to base-level. But many areas have been nearly base-leveled. Such plains are *peneplains* (almost plains). Above their otherwise nearly level surface, occasional elevations may rise abruptly. These elevations, known as *monadnocks* (Fig. 139), owe their existence to (1) the greater resistance of their rocks, or (2) a favorable position among drainage lines. The time required for reducing a drainage basin to a base-level plain is a *cycle of erosion*. As implied above, cycles of erosion commonly are brought to an end by relative uplift of the land before they are completed.

The terms youth, maturity, and old age, as used in geography, apply to *stages of development*, and not to periods of years. Thus a small river, working on soft material, may bring its valley to old age in less time than that required for a large stream, opposed by resistant rocks, to bring its valley to maturity.

Influence of stage of erosion on human activities. The density of population of a region and the condition and activities of its people are influenced greatly by the stage which it has reached in its topographic development. Many young rivers are interrupted by falls and rapids (p. 230) which afford water power for manufacturing, but interrupt or prevent navigation. Many young rivers, too, are not available for commerce partly because they flow in narrow valleys, far below the level of the surrounding country. In parts of western United States, it is also impracticable to lift the waters of such streams to the neighboring uplands for purposes of irrigation. Thus the waters of the Colorado River can be used for irrigation only in the upper part of the river system, or below the Grand Canyon, and the larger irrigation projects of southern Idaho are related definitely to breaks in the walls of the deep canyon of the Snake River. Again, very deep valleys may make travel across their courses almost impossible. In such cases, places where the valleys can be crossed may have all the importance of mountain passes, controlling the courses of trails and roads. The Denver and Rio Grande Railroad crosses the Green River in eastern Utah where there is a gap in the canyon wall, a gap that earlier fixed the course of the Spanish Trail. Roads may run in any direction over young plains whose valleys are shallow. Nearly all the land of such plains can be farmed, so far as topography is concerned. The poorly drained inter-stream flats may require ditching or tile draining, however, as in parts of Iowa and Illinois.

Where relief is great, early maturity is least favorable to most human activities. The larger rivers may be navigable, but most of their tributaries are likely to have steep gradients, with falls and rapids. At this stage, run-off is at a maximum, and streams are most subject to floods. Many of the larger rivers are crossed at ferries and fords, for bridges are hard to maintain. Good sites for river towns may be few. Wagon roads and railroads follow the narrow ridges between the valleys, or the flats of the larger streams. Farming is difficult on the steep valley slopes, where soils are likely to be thin and easily washed away. In general, the population of such regions is sparse and non-progressive, having little contact with the outside world. Mineral deposits or other special resources may create industrial centers, whose progress serves to emphasize the backwardness of the region as a whole. These conditions are illustrated in parts of the Cumberland and Alleghany plateaus (p. 173).

Old rivers are, as a rule, free from rapids and falls, and in most cases have gradients so gentle that they do not afford good water power. While these conditions favor navigation, the latter may be interfered with by sand bars (p. 237) and the shifting and crooked courses of the channels. Much of the land of the broad flood-plains of old rivers is swampy and of little use until drained, but is then of

Fig. 140. The canyon of the Yellowstone. (Hillers, U. S. Geol. Surv.)

great fertility (Why?). While floods are most numerous in valleys whose slopes are steep, they are more likely to be disastrous to property on the broad, low flats of older rivers, such as the lower Mississippi (p. 237). On the gentle inter-valley slopes of an old area, the soils are likely to be deep (Why?); their fertility depends chiefly on the character of the underlying rock. The area of land which can be farmed is, as a rule, much greater in topographic old age than in maturity. On peneplains, as on youthful plains of low relief, travel is easy in all directions. Wagon roads and railroads are not confined to certain courses by topography.

Canyons and gorges. Valleys which are narrow and deep often are called *gorges* if small, and *canyons* if large. The Colorado Canyon is the greatest canyon known. Its depth is about a mile, and it is eight to ten miles wide at the top. Its sides are step-like, because of the unequal hardness of the rock of the canyon walls. The harder strata are the cliff-makers. The Yellowstone (Fig. 140), Snake, and Columbia rivers have wonderful canyons in some parts of their courses, and so has the Arkansas River where it flows through the Rocky Mountains. The canyons of many smaller and less well-known rivers are almost equally striking.

Fig. 141. Cliff dwellings, southwestern Colorado.

A narrow valley means that the processes which have made it deep have outrun the processes tending to make it wide. Valleys are deepened rapidly when their gradients are high and their streams strong. They are widened slowly (1) when the climate is arid, so that there is little slope wash, (2) when the stream is so swift that it does not meander, and (3) when the material of the sides is such that it will stand with steep slopes. Therefore (1) great altitude, (2) arid climate, (3) swift streams, and (4) rock which will stand in steep slopes, favor the making of canyons. In other words, young valleys in plateaus and mountains (as in western United States) are likely to be canyons. (How can there be large, strong streams in dry regions?)

Some of the ancient cliff-dwellers made their homes in the recesses of canyon walls (Fig. 141), probably because these positions could be defended easily.

Canyons must change into valleys of another type, for the stream in the canyon will in time cut down to its base-level. The valley will then stop growing deeper, but widening will still go on, and the narrow valley will become so wide that it will cease to be a canyon.

Rapids and falls. The bed of a stream may be steeper at some points than at others, and there the stream flows more rapidly. The quickened flow constitutes a *rapids*; or, if the water in a stream's bed drops over a cliff, it makes a *waterfall* (Fig. 142). Waterfalls and rapids are important chiefly because they render the power of the streams available to man for purposes of manufacturing, lighting,

transportation, etc. (p. 288). Many electric railroads and many industries depend for power on electricity developed by falls and rapids, and railroads and factories of all sorts are likely to depend on this sort of power still more largely in the future. Rapids and falls interfere with navigation, or prevent it altogether (p. 228).

Fig. 142. Falls of the Black River, Wisconsin. (Smith, Wis. Geol. Surv.)

Waterfalls come into existence in various ways. A river flowing on the high gradient shown in Fig. 143 is likely to be an eroding river. It will wear its channel faster at *A*, where the rocks are soft, than just above, where they are hard, with the result shown in Fig. 144. The continued wear of the water in such a case would cause the rapids at *A* (Fig. 144) to become steeper, and in time the descending water would become a fall (Fig. 145). In this case, *the rapids and falls depend on inequalities of hardness in the bed of the stream*. This is a common way in which falls and rapids originate. A landslide or lava flow may form a dam, over which the water falls or flows in rapids. Most of the waterfalls of the United States are due to glaciation (pp. 256, 265).

Falls and rapids are undergoing constant change, although the change is usually very slow. Many falls are moving slowly up-stream, because the water undermines the hard layer of rock over which it drops (Fig. 145). As a fall moves up-stream, it becomes lower in many cases (Fig. 145). It is clear that such falls will disappear if they recede far enough. If the hard rock over which the water drops is in the position shown in Fig. 146, the fall will not recede, though it will become lower, and will disappear when the stream cuts down to base-level, where the fall is. (What would be the effect of re-elevation of the basin?) Rapids and falls are temporary features of streams, and, like canyons, are marks of youth. In time, therefore, all existing rapids and waterfalls will disappear.

Narrows. Many valleys are narrow where they cross a tilted layer of hard rock. Such a place in a valley is a *narrows*, or *water-gap* (Fig. 147). The Delaware Water-Gap through Kittatinny Mountain (Pa.-N. J.) is a well-known example.

Fig. 143.

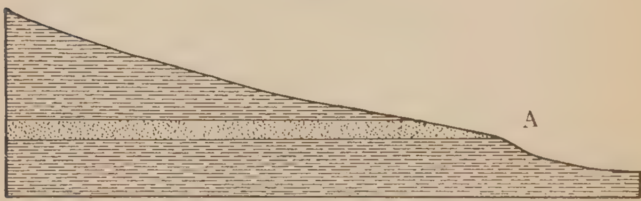


Fig. 144.

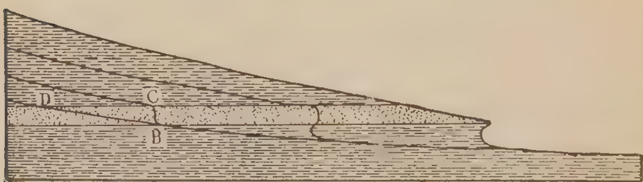


Fig. 145.

Figs. 143, 144, 145. Diagrams to illustrate the development and extinction of a waterfall.

Why will the waterfall cease to retreat up-stream when it reaches C-B, Fig. 145? What changes will occur after it reaches this place?

Narrows sometimes serve as gateways through mountains, and so control lines of travel. The narrows of Wills Creek in Wills Mountain, Maryland, may serve as an example. In the early days of American history, Fort Cumberland was built at this narrows to guard the important pass through the mountains, and Washington's and Braddock's roads ran west through it. At the present time, the Cumberland National Road (Fig. 215) and an important railway make use of it.

Accidents to streams. Streams are subject to many accidents. If the land through which they flow sinks so that its slope is reduced, they flow less rapidly, or may even cease to flow. If the lower end of a valley sinks below sea-level, the sea-water enters and forms a bay, *drowning* the lower end of the river and its valley. If the streams along a coast end in bays, we infer that the coast has sunk, and that its rivers and valleys have been drowned. Thus Delaware Bay and Chesapeake Bay are drowned valleys. If the basin of an old stream is raised so that the gradient of the stream becomes greater, its velocity is increased, and it again takes on the character of youth. Such streams are said to be *rejuvenated.*

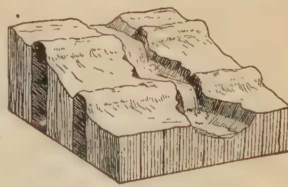
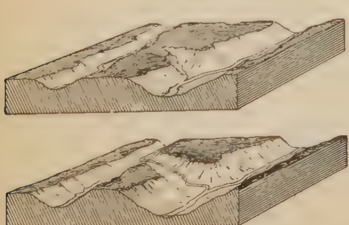


Fig. 146. Diagram of waterfalls developed on vertical beds.

Fig. 147. Lower Narrows of the Baraboo River, Wisconsin. The valley widens beyond the gap, the same as in the foreground.

If by headward growth one valley reaches and enters another where the latter is at a higher level, it may steal the water which otherwise would flow down the higher valley (Figs. 148 and 149). The stream which steals is a *pirate.* The stream stolen is *diverted,* and the stream which has lost its upper water is *beheaded.* Piracy has been rather common among rivers, especially in mountain regions. In the Appalachian region, for example, there are few large streams which



Figs. 148, 149. Diagrams to illustrate stream piracy.

have not either increased their waters by piracy, or suffered loss by the piracy of others. Piracy is favored by inequalities of hardness, for streams which do not cross hard rock deepen their channels more readily than those which do (Fig. 150).

When a stream is diverted from a narrows, the water-gap becomes a *wind-gap*. Wind-gaps are common in most mountain regions which have advanced to late maturity. Cumberland Gap, in the southeastern corner of Kentucky, is an example. It afforded many

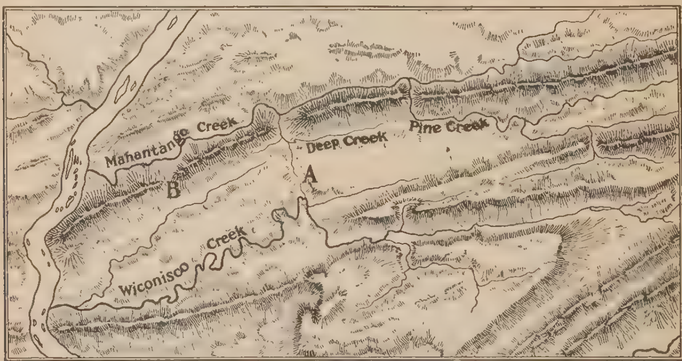


Fig. 150. A case of stream piracy in Pennsylvania. The upper part of the present Wiconisco Creek formerly was tributary to Deep Creek, joining the latter at "A." (From Millersburg and Lykens, Pennsylvania, Sheets, U. S. Geol. Surv.)

What enabled Wiconisco Creek to behead Deep Creek? What was the probable origin of the mountain gap at "B"? Is future piracy likely to occur in this region? Why?

of the early emigrants the best route across the mountains, and during the last quarter of the eighteenth century probably more than 300,000 people passed through it to settle in the West. The many wind-gaps of the Blue Ridge Mountains were important in the early westward movement of population, and again in the campaigns of the Civil War.

DEPOSITION BY STREAMS

Causes of deposition. Streams may become overloaded in various ways, and so be forced to deposit their excess sediment: (1) Their carrying power may be reduced by a decrease of gradient. The change may take place suddenly, as at the base of a steep slope, or it may take place slowly, as a stream flows through a valley whose slope becomes gradually less. (2) Their carrying power may be

diminished by decrease of volume. Streams flowing through arid regions may receive little water, and lose much by evaporation and by soaking into the dry earth. Many streams in the West leave the mountains bank-full, to wither and disappear on the lower lands. Many also have much of their water withdrawn for purposes of irrigation. (3) Tributary streams with high gradients may bring to the main streams more sediment than the latter can carry away.

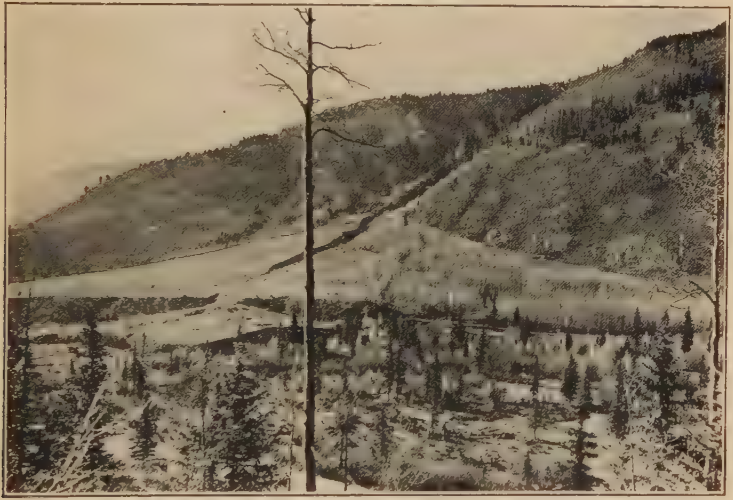


Fig. 151. Alluvial fan at the mouth of Aztec Gulch, southwestern Colorado. (U. S. Geol. Surv.)

(4) Many rivers deposit at their mouths, where the current is checked.

Deposits at the bases of steep slopes. Every shower washes fine sediment down the slopes of hills and mountains, and much of it is left at their bases, where the velocity of the water is checked suddenly. At the lower end of every new-made gully on a hillside, there is a mass of debris which was washed out of the gully itself (Fig. 127). Material in such positions accumulates in the form of an *alluvial cone*, or a gentler sloping *alluvial fan* (Fig. 151). The rivers descending from the Sierras to the valley of California have built great fans along the foot of the range, and most of the rivers coming out of the Rockies to the plains east of them have done the

same thing. Many of the fans of streams descending from the western mountains are miles across. Fans made by neighboring streams may grow until they unite to form a *compound alluvial fan*, or a *piedmont alluvial plain.* Such plains exist at the bases of many mountain ranges. Their alluvial deposits may be hundreds of feet thick.

Many alluvial fans and piedmont alluvial plains are valuable for farming. (In general, which would be more valuable, the higher

Fig. 152. Cultivated alluvial fan near Riverside, California.

or the lower portions of alluvial fans? Why?) In parts of southern California, for example, such lands are so valuable that farms are very small and highly improved (Fig. 152). Water is supplied (1) by wells, through which the fan is made to yield up the water it has absorbed, or (2) by irrigating ditches which connect with a stream or reservoir at a greater height. Many villages in mountain valleys are situated on alluvial fans. The agricultural settlements of Utah spread southward from the vicinity of Great Salt Lake along the piedmont alluvial plain at the west base of the Wasatch Mountains. Most of the cities and villages of the state are within this belt.

Deposits in valley bottoms; flood-plains and man. The gradient of a stream generally becomes less toward its mouth, and

so it happens that sediment is spread for great distances along valley bottoms. Some of it is left in the channels, and some is spread over the low lands along the streams, making *alluvial plains.*

Streams sometimes deposit sand bars in their channels, especially in low water. Bars, and the tree trunks and snags which they often catch and hold, hinder navigation, especially when rivers are low. In earlier years, many steamboats were wrecked by such obstructions in the Missouri and Mississippi rivers. Later, large sums of money were spent in removing snags and dredging channels.

Alluvial plains along large rivers are almost flat, though they slope gently down-stream, and many of them have *natural levees.* This term is applied to the low ridges along the banks of the channel (Fig. 153). In times of flood, the current in the main channel is swift; but so soon as the water spreads beyond its channel, its velocity is checked because its depth suddenly becomes less, and it promptly abandons much of its load. During the period of overflow, the edges of the channel current are checked by the slower moving flood-plain water, and this causes further deposition on the banks of the channel. Repeated deposition in this position gives rise to levees. Embankments have been built by man upon the natural levees of some rivers to prevent the flooding of the valley flats, and to permit the settlement of the bottom lands. Louisiana alone has spent more than $35,000,000 since 1865 in levee building, and is expending now about $800,000 a year in this way. (Why must the protective levees be built higher and higher as time passes?) In spite of such improvements, floods are unfortunately frequent. The damage which they did to buildings, bridges (Figs. 154 and 155), railroads, etc., in the United States in 1908 was estimated at more than $237,000,000, though not all this damage was done on the flood-plains of large rivers. Impressive as this estimate is, it takes no account of the great damage done to the land itself, nor is it possible to measure the suffering and reduced efficiency of the people living where there have been great floods.

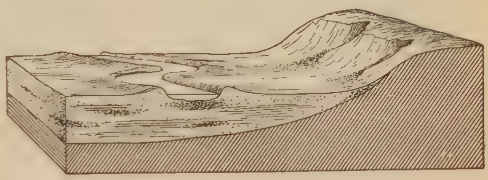


Fig. 153. Diagram showing natural levees.

In early days, most of the people in Louisiana and Mississippi lived in narrow belts along the levees of the Mississippi and its

Fig. 154. Railway bridge over the Nolichucky River at Unaka Springs, Tennessee. (From photograph by Glenn, U. S. Geol. Surv.)

Fig. 155. Same place as shown in Fig. 154 after the bridge and piers were swept away by the flood of May, 1901. (From photograph by Glenn, U. S. Geol. Surv.)

branches. The land here was high enough and dry enough to be farmed, very fertile, and close to the streams which were the great highways of that time. The plantations were narrow along the streams, and extended back, at right angles to them, until the land became too low and wet to cultivate.

A stream in an alluvial plain is likely to wind about, or *meander* (Fig. 156). This is the result of the low velocity of such a stream, for sluggish streams are turned aside easily. Were such a stream made straight, it would become crooked again, for the banks of all streams are less firm at some places than at others, and the stream would cut more at those places. Once started, meanders tend to become more and more pronounced (Fig. 157) until, probably in some time of flood, the stream cuts through the neck of the meander and straightens its course. When a stream has cut off a meander, the abandoned part of the channel may remain for a time unfilled with sediment. If it contains standing water, it becomes the site of an *oxbow lake* or *bayou* (Fig. 156).

Fig. 156. The Rio Grande near Brownsville, Texas.

In meandering, a stream sometimes reaches and undermines the valley bluff, thus widening its valley flat. This is, indeed, the most important process in the widening of valley flats (p. 223). Towns grew up early on the bluffs of the lower Mississippi at points where the river touched the side of its valley. In this way the location of Natchez, Vicksburg, Memphis, and other places was determined. Such sites, overlooking and controlling the river, were bones of contention between Spain and the United States during the dispute over the southwestern boundary, from 1783 to 1795. The same physiographic features located the Confederate defenses in the Civil War at Columbus (Ky.), Ft. Pillow (Tenn.), Vicksburg (Miss.), Grand Gulf (Miss.), and Port Hudson (La.).

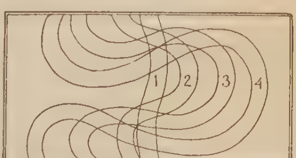


Fig. 157. Diagram showing development of a meander.

By shifting their courses, as the result of deposition and meander-

ing, streams have affected human interests in many other ways. Villages which grew up on the banks of navigable rivers because of the river trade, in some cases have been left far from the streams by changes in the positions of the latter. Such villages usually decline when the streams withdraw their patronage. Other places built on river banks have been preserved at great expense, while some have been washed away. The Mississippi River flows over the site of Kaskaskia, one of the most important French settle-

Fig. 158. A delta in a lake in Switzerland. (From photograph by Robin.)

ments in the upper Mississippi Valley, and the first capital of Illinois. The Missouri River destroyed Franklin, Missouri, an outfitting place in the 1820's for the trade across the Great Plains to Santa Fé.

Many streams have been used as boundaries between counties and states. In numerous cases the shifting of the stream has led to boundary disputes, for, by the cutting off of meanders, tracts of land have been shifted from one state to another. In the case of the Missouri River, there have been disputes between Nebraska and South Dakota, Nebraska and Iowa, and Nebraska and Missouri. The Supreme Court finally decided that when the Missouri develops a cut-off, the boundary line does not shift with the river, but remains where it was. Again, many boundaries have been defined as following the "main channels" of streams. Where there are several channels, which is the case in many rivers, the question may arise as to which one is the main channel. Furthermore, the main channel at one time may be a subordinate channel at another time. These conditions have led to disputes over the ownership of islands in different rivers.

The objections to rivers as boundaries are most serious where they form international boundaries. Thus the shifting of the Rio Grande makes it a poor boundary between the United States and Mexico. In addition, so much water was taken from the Rio Grande for irrigation in southern Colorado and New Mexico that there was little water for Mexican farmers below El Paso. Mexico protested to the United States, and finally it was arranged that the United States should build

a great reservoir on the Rio Grande north of El Paso, to store the water of the river, and that Mexico should receive a certain fixed amount of water from this reservoir each year.

Most flood-plains are very fertile, but many are too wet to be cultivated without drainage. About one-sixth of Arkansas, for example, is swampy, but most of its swamp area is rich alluvial land. When drained, the wet lands of the United States will form one of the greatest resources of the nation (p. 300).

Deltas and their relations to man. Where a stream flows into the sea, or into a lake, its current is checked promptly, and

Fig. 159. The lower part of the delta of the Mississippi River.

soon stopped entirely. Its load therefore is dropped, and if not washed away by waves and currents, makes a *delta* (Fig. 158). That part of a delta above the surface of the water in which it is built is like a nearly flat alluvial fan. Deltas may be built where one stream flows into another, especially where a swift stream with much sediment joins a slow one.

Much land has been made by the growth of deltas. Thus the Colorado River has built a great delta across the Gulf of California near its former upper end. In the arid climate of the region, the shut-off head became a nearly dry basin, the lowest part of which is about 300 feet below sea-level. The soil being good, water alone was needed

to make this area fertile, and the results that have followed the irrigation of parts of it justify its new name, the "Imperial Valley." Figs, dates, and other tropical products grow here luxuriantly. The deltas of the Mississippi (Fig. 159), the Nile (Fig. 160), and the Hwang-ho (Fig. 161) rivers are among the large and well-known ones. The delta of the Ganges and Brahmaputra has an area (above water) of some 50,000 square miles (nearly as large as Illinois).

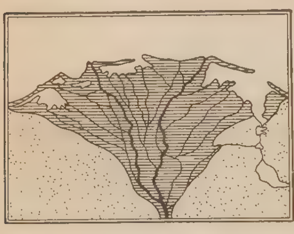


Fig. 160. Delta of the Nile River. The dotted area is desert.

While rivers have made much delta land, it is to be remembered that the material of which they are composed has been removed from vastly larger areas, and that much of it was rich soil. It is probable that the loss to man through the removal of such material is far greater than the gain resulting from its deposition.

The surfaces of most deltas are nearly flat, and the streams which cross them often give off branches, called *distributaries*, which flow independently to the edge of the delta, and are subject to frequent changes. These changes sometimes affect commerce in a vital way (p. 351). The distributaries of the Mississippi offered the English in the War of 1812, and the Federals in 1862, several possible lines of approach to the vicinity of New Orleans. The necessity of watching these different lines scattered the men and the resources, and weakened the resistance of the defenders of the city. By cutting the levees and flooding the lower land, General Jackson was able to increase greatly the difficulties of the English.

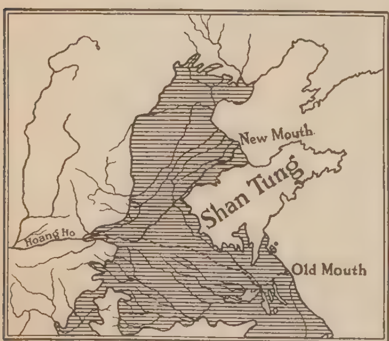


Fig. 161. Delta of the Hwang-ho.

Most delta land away from natural levees is low and wet, and must be diked and drained before it can be farmed. The soil of great deltas is deep (What determines its thickness?), and in most cases rich in the mineral elements of plant food. Some deltas, like that of the Hwang-ho, support dense populations. Delta lands are, however, subject to disastrous floods. It is estimated that the flood of the Hwang-ho

River in September, 1887, drowned more than a million people and caused the death of many more by disease and famine afterward.

Previous to 1853, the Hwang-ho had flowed for many years into the Yellow Sea south of the Shan-tung promontory (Fig. 161). In that year, it shifted its course in flood time, forming a new channel leading northeast into the Gulf of Pechili, 300 miles north of its former mouth. Other changes at earlier times, running as far back as 2293 B. C., are recorded in the annals of Chinese history.

Lakes exist on many large deltas. Some are former sections of the shifting streams, and some (Fig. 159) are portions of the sea or lake in which the delta is built, portions that were surrounded by the deposits or shut in between them and the former shore-line.

Delta cities have peculiar problems, as illustrated by New Orleans. For a long time, floods were of almost yearly occurrence. In 1849, for example, 220 inhabited squares were flooded and 12,000 people were driven from their homes. Street improvement was difficult; there were no paving stones save those brought as ballast in ships. As late as 1835, only two streets were paved for any considerable distance. On the other streets, carriages in wet weather sank to the axle in mire. The question of a domestic water supply was an early and pressing one, and for a long time the practice was general of building cisterns to catch the rainwater. The city could not easily empty its sewage into the Mississippi, for the banks of the river are above the houses. Under these conditions, the city was for years a very unhealthful place. In recent years these disadvantages have been largely overcome. New Orleans now pumps its sewage into the river, cisterns are condemned, many streets are well paved, and the city is much more healthful than formerly.

Alluvial terraces. When a river which has an alluvial flat is rejuvenated (p. 233), the stream sinks its channel below the level of the flat. The remnants of the old flood-plain are then *alluvial terraces* (Fig. 162). Such terraces are also formed in other ways. Thus if a stream is supplied for a time with an excess of load, it *aggrades* (builds up) its valley. If, later, the excess of sediment ceases, the stream sets to work to remove that which was temporarily laid aside in its flood-plain.

The material of many alluvial terraces is gravelly or sandy, and their soils vary greatly in value. Many towns and cities are built on alluvial terraces. (What advantages would such locations have over sites on flood-plains? On the edges of valley bluffs?) The leading towns of the Platte Valley in Nebraska are on terraces near the mouths of tributary valleys. (Of what significance is the last fact?) In the middle Illinois Valley, every town is on a terrace, and every terrace has a town. Terrace sites were chosen for most of the first settlements of the Connecticut Valley, such as Hartford, Weathersfield, and Windsor.

Summary. From the physiographic standpoint, the mission of running water is to wear the land to base-level. The material it

Fig. 162. Terrace of the Columbia River. (Willis.)

carries toward and to the sea is prepared for transportation largely by the agents of weathering, and in subordinate amount is worn from the solid rocks by the streams themselves. The irregular wearing down

Figs. 163, 164. Drainage maps of contrasted areas of equal size.

of the land produces most of the familiar relief features of the surface. Their characteristics are determined by several factors, especially

by the character and position of the rocks from which they were carved, and the stage of development which they have reached. On its way to the sea, the waste of the land is often laid aside by overloaded streams, forming topographic features subject to later destruction by eroding waters or by other agencies. All phases of river work affect human interests vitally. Much can be done by regulating and controlling streams to increase their usefulness and prevent their doing damage.

Fig. 165.

QUESTIONS

1. In what parts of the United States would a valley need to be deep to have a permanent stream?

2. What are all the conditions which may help to make the flow of streams (1) regular, and (2) irregular?

3. Why do streams carry more and coarser material during floods than at other times?

4. Is the bed of the upper St. Lawrence River being eroded much? Why?

5. (1) Why is the rate of erosion in the Colorado Basin so rapid (Fig. 126), especially in view of the fact that a large part of it is in an arid region? (2) Why is the rate in the basin of the Red River of the North relatively so slow (Fig. 126)?

6. Why are steep slopes characteristic of arid climates?

7. What is the age, in terms of erosion, of the area shown in Fig. 80?

8. (1) Interpret the contrasted drainage shown by Figs. 163 and 164. (2) In what stage of erosion is the area shown by Fig. 163? (3) Does Fig. 164 indicate the stage of erosion which that area has reached? Why?

9. (1) What topographic features are shown in Fig. 165? (2) Compare and contrast the northern and southern parts of the area as to (a) the climate, (b) the character of the rocks, and (c) the work of the streams.

10. In general, what stream-built features are (1) most, and (2) least enduring? Why?

11. State all the important ways in which (1) stream erosion and (2) stream deposition affect human interests.

The Work of Ice

Snow is perhaps the most common form of ice, but ice on ponds, lakes, and rivers is familiar to all who live where winters are cold. In middle latitudes the water in the soil and rocks freezes in winter, often to a depth of several feet. In some parts of the world, too, there are glaciers. In most of its forms ice has some effect on the surface of the land.

Ice on lakes and rivers. Most lakes and rivers in middle latitudes are frozen over for several months each year. This is in some cases a great disadvantage from the standpoint of commerce. The upper Mississippi River is closed to navigation for more than four months of the year. The open season on the upper Great Lakes lasts about seven months. The St. Lawrence River is closed by ice about five months each year, and is difficult to enter during another month. Hudson Bay and its tributary rivers are closed even longer. It was a great disadvantage to the French colonies of interior Canada that they were shut off completely from the mother country for nearly half the year, and it is a serious disadvantage to Canada today that her two main gateways from the Atlantic Ocean are closed so much of the time. The inland waterways of England and France are open throughout normal years; those of Germany and central Russia are closed more often, and for longer periods the farther they are from the Atlantic. Those of northern Russia are closed for five or six months. (Why are the waterways of western Europe so in contrast with those of North America in corresponding latitudes?)

In some cases, the ice of rivers and lakes serves a good purpose. Fishing villages formerly were built on the ice in such places as Saginaw Bay, Michigan, and are still common in the gulfs of Bothnia and Finland. When frozen over, many northern rivers serve as roadways for local business. The cutting and packing of ice for sale during the following summer is an important industry on many lakes and rivers in northern United States.

Ice on the sea. In high latitudes ice forms on the sea where the water is shallow, and in polar regions it becomes several feet deep, even on the open sea. Sea-ice is broken up in the summer, and the floating pieces are called *floe-ice*. When the floes are crowded together, they make *ice-packs*, some of which are hundreds of miles across. Ice-packs are obstacles to polar navigation, and make most of the north coast of Russia and Siberia useless even in summer.

The closing of ocean harbors and of seas connected with the ocean, like the closing of inland waters, is a great hindrance to commerce. The North Sea has a tremendous advantage over the Baltic in this regard. The shores of the latter are hampered by ice each winter, while those of the former are edged with ice only during the most severe weather. The key to Russian expansion since the days of Peter the Great has been the attempt to secure ice-free harbors.

EXISTING GLACIERS

General

Conditions for glaciers. Where it is so cold that snow lasts from year to year over any considerable area, the snow constitutes a *snow-field* (Fig. 166). Snow-fields occur in mountains in nearly all latitudes, and in polar regions even down to sea-level. Where snow accumulates

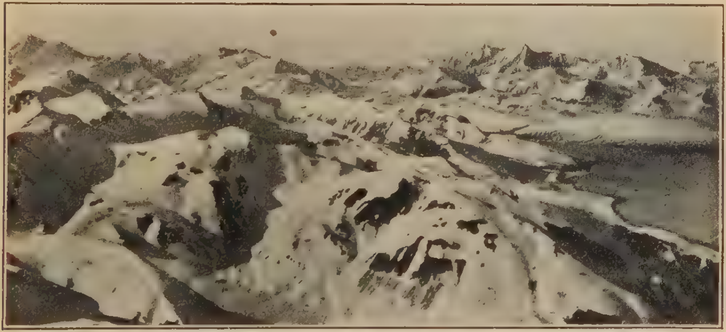


Fig. 166. Snow-fields in Alaska. Russell Fiord at right of view. (Brabazon, Canadian Boundary Commission.)

to great depths and lies long on the surface, it changes to compact ice, and becomes an *ice-field*. The beginning of this change is distinct in banks of snow which last for some weeks. Such banks are made up of coarse granules of ice, sometimes as large as peas. The change from flakes of snow to granules of ice is due, in part, to the melting of the snow and the re-freezing of the water. If there is much snow, it is compressed by its own weight, and after being compacted in this way, the freezing of the sinking water binds the granules together. When the amount of ice made from snow becomes great enough, it moves out slowly from the place where it was formed to lower and warmer places. When it begins to move, it becomes a *glacier*.

Functions of glaciers. (1) One mission of glaciers is to return to lower and warmer levels moisture which otherwise would be locked up indefinitely as snow and ice. (2) Like rivers, glaciers wear the land and move the resulting waste toward the sea. (3) Long after glaciers

Fig. 167. A valley glacier in the Cascade Mountains, Washington. (Willis, U. S. Geol. Surv.)

have melted away, some of their effects on the conditions of life remain, because of the changes they made in topography, soil, and drainage. Thus past glaciation is a leading factor in the geography of northern United States and northern Europe. (4) Glaciers tend to maintain a relatively uniform volume in the streams which flow from them, and in various mountain regions such streams afford great amounts of power.

Types of glaciers. Glaciers have various forms, depending on the amount of ice and on the shape of the surface beneath and around them. If the snow-field which gives rise to a glacier is at the upper end of a mountain valley, the ice moves down the valley as a *valley glacier* (Fig. 167). In high latitudes, snow-fields and ice-fields may lie on plains or plateaus. When the ice in such situations begins to spread, it moves in all directions from its center. Such glaciers are *ice-caps* or *ice-sheets.* Very large ice-caps sometimes are called *continental glaciers.* The main ice-caps of Antarctica and Greenland (Fig. 168) are large, but small ones are found on various promontories along the coast of Greenland, on Iceland, and on some other Arctic islands. Glaciers occur also at the bases of some mountains, being formed by the union of the spreading ends of valley glaciers. Such glaciers are *piedmont glaciers.* Of these types, valley glaciers are most common and most familiar, but the large ice-caps contain much more ice.

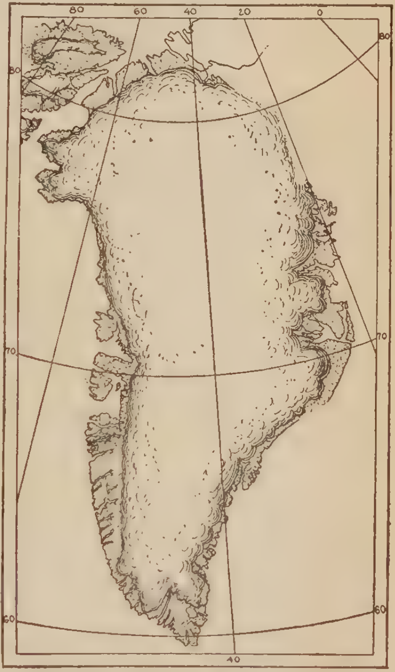


Fig. 168. Map of Greenland ice cap.

Valley Glaciers

Distribution. The chief regions of valley glaciers are the high mountains of Eurasia, the southern Andes, and the higher mountains of northwestern United States and western Canada. In Alaska, high mountains near the coast receive abundant precipitation from the ocean winds. The heavy snowfall on the upper slopes feeds many glaciers, some of which reach the sea.

The glaciers of Switzerland are known best and help to attract thousands of tourists to that country each year. In 1910, Congress created Glacier National Park on the Continental Divide in northwestern Montana (Fig. 224). It is about

sixty miles in length and contains more than sixty glaciers. This may become one of the best known and most visited of our National Parks, for the mountains and glaciers offer the chance for mountaineering of real Alpine character, the streams abound in trout, and the mountains still shelter enough game animals to become an important game refuge. The park contains one of the most beautiful portions of the Rocky Mountains lying within the United States.

Size. There are nearly 2,000 glaciers in the Alps, only one of which has a length of ten miles. Less than 40 have a length of five miles, while the great majority are less than one mile long. Only a few are so much as a mile wide, and none are more than a few hundred feet thick. Larger glaciers occur in the Caucasus Mountains and in Alaska. Seward Glacier in Alaska is more than 50 miles long, and is three miles wide at the narrowest place. The glaciers of western United States south of Alaska are not so large as the larger glaciers of the Alps.

Movement. The ice of a glacier is wasting all the time, both by melting and evaporation. In spite of this, many glaciers remain about the same size year after year. This is because the loss by melting is replaced by advance from the snow-fields, from which the ice creeps down the valleys until it reaches a place so warm that the melting at the end balances the forward motion. Most glaciers move very slowly. Of those whose rate of advance has been measured, few move more than two feet a day, and very few as much as seven.

The rate of movement depends chiefly on (1) the thickness of the moving ice, (2) the slope of the surface over which it moves, (3) the slope of the upper surface of the ice, and (4) the topography of its bed. (What combination of conditions would favor most rapid movement?) The exact nature of glacier movement is a disputed question. It was thought formerly that glaciers flowed somewhat as stiff liquids do, but it is very doubtful if the motion is really flowage.

Ice-Caps

As already stated, ice-caps may lie on plains or plateaus, and may be large or small.

Greenland has an area of 400,000 to 600,000 square miles, and all but its borders is buried beneath one vast field of ice and snow (Fig. 168). Except on a narrow border of a mile or so at the edge of the ice-sheet, not even a bowlder or a pebble interrupts the great expanse of white.

The thickness of the Greenland ice is not known, but, where thickest, it is probably thousands of feet. Near its margin the ice is much crevassed, but the interior is fairly smooth so far as known. The ice of this great field is creeping slowly outward. The rate of

movement never has been measured, and is probably not the same at all points, but it has been estimated not to exceed a foot a week. This ice-cap is, in one sense, more of a desert than the Sahara, since it is inhabited even less than the latter.

Where the edge of the Greenland ice-cap lies a few miles back from the coast, the rock plateau outside it has many valleys leading down to the sea. Where the edge of the ice-cap reaches the heads of these valleys, ice moves down them, making valley glaciers. Many of the latter ~~reach the sea,~~ where their ends are broken off and float away as icebergs. This is the source of most of the bergs (Fig. 169) seen from steamers which cross the North Atlantic. Some are so large that they float far to the south before they are melted. Since they are sometimes surrounded by fog, they are a menace to ships (p. 149).

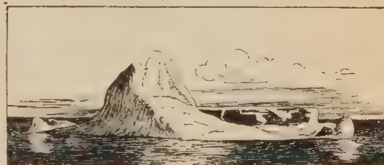


Fig. 169. An iceberg.

The Antarctic snow-and-ice-cap is much larger than that of Greenland, but its area is not so well known. It is probably several million square miles in extent, and the thickness of its ice probably exceeds that of Greenland. The ice descends to the sea at many points, and huge blocks of it become icebergs.

Piedmont Glaciers

A number of alpine glaciers come down adjacent valleys in the St. Elias range of Alaska, and spread out on a low plain at its base. So much do their ends spread that they unite to form a single body of ice, 70 miles long and 20 to 25 miles wide, called the *Malaspina Glacier.* Its area is greater than that of Delaware. Its central portion is free from debris, but has thousands of deep, wide cracks. A belt along the margin of the glacier five miles or less in width is covered by rocky and earthy debris, and parts of it are clothed with vegetation. The undergrowth is here so thick that travelers have to cut paths, and on the edge of the ice there are trees three feet in diameter. Other glaciers of the same type occur about North Greenland.

Muir glacier

ANCIENT GLACIERS

There have been times when glaciers were much more extensive than now, for various features produced only by glaciation (pp. 255-

265) are found in many places now free from ice. The latest of these periods is known as the *Glacial Period*. In this country, glaciers existed even in the mountains of New Mexico, Arizona, and Nevada.

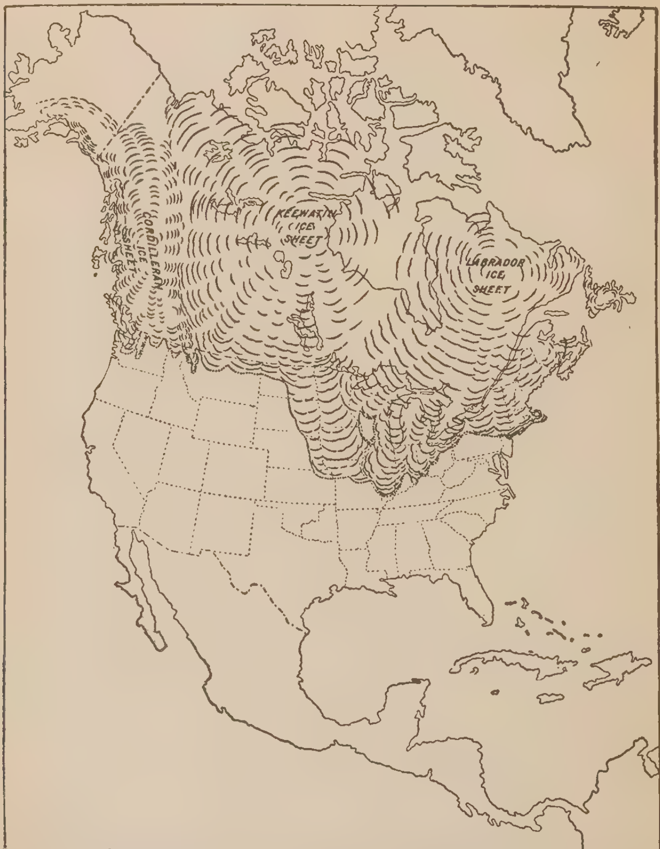


Fig. 170. Sketch-map showing the area in North America covered by ice at the stage of maximum glaciation. (Chamberlin.)

The amount of ice in the glaciers of Utah or Colorado was then far greater than all that now exists in the United States south of Alaska. At the same time, a great area east of the Cordilleran mountain system, some 4,000,000 square miles in extent (Fig. 170),

and lying partly in Canada and partly in the United States, was covered with an ice-sheet.

The ice-sheet of North America originated in two principal centers, one on either side of Hudson Bay. The beginning of each was doubtless a great snow-field. At first these snow- and ice-fields grew by the addition of snow, and later also by the spread of the ice to which the snow gave rise. The two ice-sheets finally became one by growing together. This great continental glacier did not originate in mountains, but on high plains.

When largest, the ice-sheet had the extent shown in Fig. 170, but there was an area of 8,000 to 10,000 square miles, mainly in southwestern Wisconsin, over which the ice did not spread. This is known as the *driftless area*, because there are no ice deposits (*drift*) in it. In the Cordilleran mountains there was also a great body of ice that remained somewhat distinct from the one which spread from the other centers.

There was extensive glaciation in Europe at about the same time. The glaciers of the Alps were then many times as large as those of to-day. On the south they extended quite beyond the mountain valleys, and spread out on the plains of northern Italy, where they left their deposits. Similar conditions existed in the other mountains of Europe where glaciers now exist, and in some where they do not. There was also a large ice-sheet in northwestern Europe, but its area was only about half that of the ice-sheet of North America. The principal center from which the ice spread was the mountains of Scandinavia.

Great ice-sheets are not known to have developed in other continents during the Glacial Period, but their valley glaciers were very large.

The history of the Glacial Period was not simple. After the growth of the first great North American ice-sheet, it shrank to small size, or disappeared altogether. Then followed a relatively warm period, when plants and animals lived in the region where the ice had been. Another continental ice-sheet then spread over the region from which the first had melted, and extended still farther south. As it advanced, the second ice-sheet in places buried the soil which had formed on the drift left by the ice of the first epoch. Such soils, here and there containing the remains of plants which grew in them, are one means by which it is known that there was more than one ice-sheet. A third, fourth, and fifth ice-sheet, each somewhat smaller than its predecessor, came and then melted. In other words, there were several epochs when ice-sheets were extensive, separated by epochs when they were much smaller, or when they had disappeared altogether. The ice-sheets of Europe had a similar history.

Cause of glacial epochs. The development of the great ice-sheets was due to a change in climate, and especially to a reduction of temperature. The cause of the cold is not known, though many explanations have been suggested. The explanation which seems most acceptable is that the change of climate was due to a

Fig. 171. Glaciated surface of limestone. The view shows also the relation of drift to the bed-rock beneath. Kelleys Island, Ohio. (Stauffer.)

change in the constitution of the atmosphere. An increase in the amounts of carbon dioxide and water vapor would make the climate warmer (pp. 31, 178), while any great decrease in these things would make the climate much colder. Good reasons have been suggested for variations in the amounts of these substances in the air, and also for the heavy snowfall in the regions where the ice-sheets existed. Heavy snowfall is quite as necessary as low temperature for extensive glaciation.

CHANGES DUE TO GLACIAL EROSION

How glaciers erode. Clean ice, moving over smooth, solid rock, would erode little, but ice carrying pieces of rock in its bottom wears the surface, even when the latter is smooth and solid. Like wind and water, therefore, ice erodes by means of the rock tools which it carries. Each kind of tool does its appropriate work. Fine, earthy material in the bottom of the ice polishes the rock below, while sand and small pebbles make scratches (*striæ*) upon it. Grooves are made by bowlders held in the bottom of the ice and forced along under

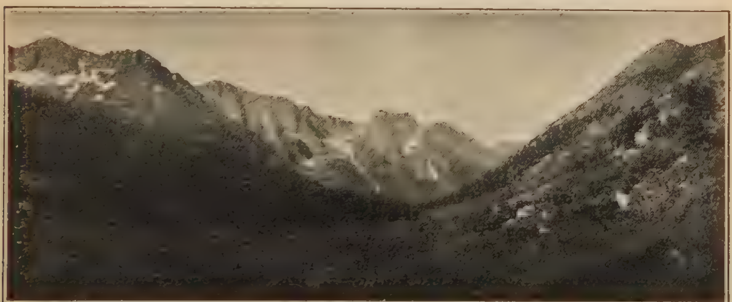


Fig. 172. Glacial trough in San Juan Mountains, Colorado.

great pressure. Meanwhile the tools are themselves polished, scratched, and worn smaller. The finest products of the grinding have been called *rock flour.* Polished and striated bed-rock surfaces (Fig. 171) are among the clearest marks of the former existence of glaciers in many places now free from ice.

Changes in valleys. Mountain valleys through which glaciers pass are widened and deepened, and their walls made smoother (Figs. 172 and 173). In many cases the heads of glaciated valleys are big, blunt, and steep-sided. Most of the lakes which add so much to mountain scenery are (1) in rock basins gouged out of valley floors by glaciers (Fig. 173), or (2) behind dams formed by the deposits of the ice (Fig. 186). Tributary valleys commonly join their main valleys at the level of the latter, but the bottoms of many valleys that were deepened and widened by former glaciers are much (in some cases 500 to 1,000 feet) lower than the lower ends of their tributaries. In such cases streams descend in rapids or falls from the tributary *hanging valleys* (Fig. 174). Much water power is afforded

by such rapids and falls in the mountains of western United States, Switzerland, and northwestern Europe.

The ancient ice-sheet overrode hills and divides as well as valleys. In many cases the ice deepened the valleys more than it lowered the hills, and where this was true it increased the *relief*, even though it reduced the *roughness* of the surface.

Elevations reduced and changed in shape. Hills overridden by ice-sheets are worn down and smoothed off, and the wear is

Fig. 173. A valley in the Needle Mountains, Colorado, cleared of all earth and loose rock by a glacier which once passed through it. The moving ice also smoothed all the projecting points of rock.

greatest on the side of the hill against which the ice moves (Fig. 175). Many small elevations were worn away entirely by the continental glaciers.

Ice-shaped coasts. Glaciers which descend into the sea through bays tend to gouge out the bay-bottoms, and to wear back the bay-heads. If such glaciers melt away, the sea enters to form long, narrow, steep-walled re-entrants, ~~called~~ *fiords*. Norway (Fig. 176), Scotland, Maine, and Alaska have fiord coasts, though all of them owe their characteristics in part to sinking. Many islands front

these coasts, most of them representing the higher parts of the old land whose surroundings have been drowned.

GLACIAL DEPOSITS

General characteristics. Most of the material transported by a glacier is carried in its lower part; but some is carried in the ice above its bottom, and some on top of the ice. All of it is left, finally, on the surface of the land. The materials deposited by glaciers, called *glacial drift* or *till*, range from finest earth to huge bowlders (Fig. 177). They are not stratified, and in many places are so deposited as to form distinctive topographic features. Much of the drift deposited by the continental glaciers is a thorough mixture of many kinds of material, for it was derived from a vast area within which many kinds of rocks occur. (Compare glacial drift with stream deposits.)

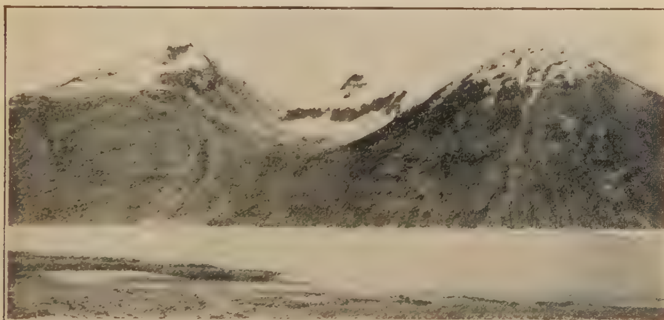


Fig. 174. Hanging valley; Nunatak Fiord, Alaska. (Tarr, U. S. Geol. Surv.)

Fig. 175. A hill smoothed by the glacier ice which overrode it. Shore of North Greenland. (From photograph by Chamberlin.)

Leading types. When the end of a valley glacier or the edge of an ice-cap stays in the same place for a long time, a thick body of

drift is lodged beneath it, for drift is brought to this position all the time by the oncoming ice, and left there. Such a deposit is a *terminal moraine* (Fig. 178). All the other drift deposited by an ice-sheet is *ground moraine*. After a glacier melts, the area of ground moraine is

Fig. 176. The Sogne Fiord, coast of Norway. (Robin.)

not as great as the glaciated area, for glaciers do not carry debris in all parts of their bottoms. In general, the drift is thickest and covers the largest proportion of the surface near the margins of a glaciated area, and is thinnest and least continuous in the region from which the ice spread (Why?). For this reason, there are large areas of bare rock and of thin, bowlder-strewn soil on the uplands of eastern and northeastern Canada. Together with a bleak climate, these conditions render large areas unfit for farming. Much of the material removed by the ice from Canada was deposited in the United States. The *lateral moraines* are left along the sides of a valley after the valley glacier is melted (Fig. 179). Some of them are hundreds of feet high.

Fig. 177. Section of unstratified drift near Henry, Illinois. (Crane.)

Surface features. Because glaciers distribute their drift very unevenly, large areas once covered by ice are marked by hillocks,

mounds, and ridges of drift, and by basin-like or trough-like depressions. These features are most pronounced in terminal moraines, the surfaces of which may be distinctly rough and hummocky (Fig. 180).

Fig. 178. A glacier in the Cascade Mountains, Washington. Shows spreading end of glacier, crevasses in ice, and terminal moraine. (Willis, U. S. Geol. Surv.)

In the Lake States, the rougher parts of the terminal moraines commonly are used for woodlots and pastures (p. 173), for the surface is too uneven and the soil too coarse and stony to be cultivated successfully, in competition with the neighboring prairies. Many of the hollows in the surface of the drift contain lakes (p. 261), ponds,

and marshes (p. 300). It is estimated that there are 4½ million acres of marsh land in Minnesota, nearly as much in Michigan, and 2½ million in Wisconsin. The total swamp area for the three states is larger than the combined area of Massachusetts, Connecticut, Rhode Island, and Delaware. Nearly all this swamp land is the result of glaciation.

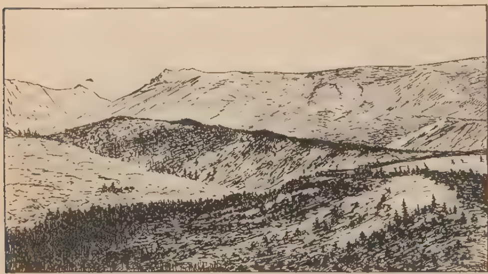


Fig. 179. A lateral moraine left by a former glacier in the Bighorn Mountains of Wyoming. (From photograph by Blackwelder.)

The surface of the drift is very unlike that developed by the erosion of running water, for in the latter the depressions have outlets, and the hills and ridges stand in a definite relation to the valleys.

The drift left by the continental glacier increased the relief in some places (Fig. 181), with unfavorable results; but in most places

Fig. 180. Terminal moraine topography near Oconomowoc, Wis. (Fenneman.)

it decreased relief and left the surface less rough than before (Fig. 182). This made it easier to cultivate the land and to build roads. Most of the surface between the Ohio River and the Great

Lakes appears to have been made smoother. But for glaciation, much of this region probably would have a maturely eroded surface, not unlike that of the driftless area, and a poorer soil than it now has.

Fig. 181.

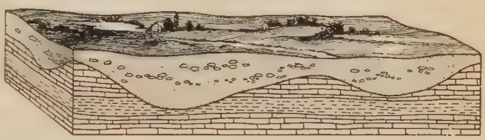


Fig. 182.

Fig. 181. Diagram showing how a nearly level surface may be replaced by a rough one through the uneven deposition of drift.

Fig. 182. Diagram showing how glacial drift may replace a hilly surface with a fairly level one.

Deposits beyond the land. Glaciers which descend into the sea may build submarine banks and even islands. Along the eastern coast of North America, these deposits may have reached the edge of the continental shelf in some places. Martha's Vineyard, Nantucket, and Long Island are composed largely of drift. The sheltered waterway behind Long Island favored the early growth of sea interests in southern New England.

Fig. 183. Map showing the abundance of lakes in parts of the glaciated area. (From Barrett, Minnesota, Sheet, U. S. Geol. Surv.)

Glacial lakes. The thousands of lakes in northern United States (Fig. 183) and Canada are nearly all of glacial origin. Some are in basins gouged out of the bed-rock (Fig. 184); some are in the

unfilled portions of drift-choked preglacial valleys; and many are in hollows in the surface of the drift (Fig. 185). The terminal moraines of many valley glaciers form dams, ponding the waters of the streams above, making lakes (Fig. 186).

The smaller and shallower of these lakes and ponds are being destroyed rapidly by (1) the sediment washed into them from the tributary slopes, and (2) vegetable matter. Some are being drained slowly (Why slowly?) by the erosion of their outlets. In the future, many of the shallower ones will be drained by man, that he may use their bottoms as farm land. It has been estimated that there are 8,000 lakes, big and little, in Minnesota, and that half of them will be destroyed by natural processes within fifty years. Connecticut has been credited with having had some 4,000 lakes at the close of the Glacial Period; 2,500 of them have been destroyed, and the sites of many of them now form choice garden spots. In southern Michigan and Wisconsin many early settlers located their farms on the bottoms of former lakes, attracted by the flat land and the fine, easily-worked soil.

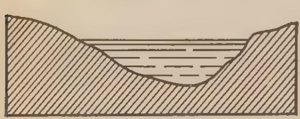


Fig. 184. Section of a lake in an ice-scoured rock basin.

Fig. 185. Section of a lake lying in a hollow in the surface of the drift.

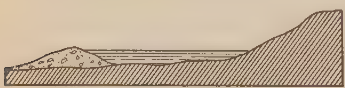


Fig. 186. Section of a lake behind a barrier of drift.

Deposits of *marl* occur in and about some glacial lakes. This marl is a soft, limey earth, the calcium carbonate of which is contributed chiefly by the shells of fresh-water mollusks and by lime-secreting lake plants. In parts of Michigan and northern Indiana, these deposits are used in making Portland cement.

The lakes and swamps of the glaciated region make the streams flow more steadily through the year by holding back some of the water of wet times, letting it flow out in times of drought. The drift itself exerts a similar influence, for, on the whole, it is thicker than the mantle rock of other regions, and therefore absorbs more water, which it yields up slowly, making the supply of ground-water to streams more steady than it would be otherwise. Thus floods are less numerous and less dangerous, and the value of the streams for navigation and power is increased. By reducing or preventing floods, the porous drift and the lakes also greatly reduce soil erosion.

Certain lakes which came into existence along the margin of the continental glacier disappeared with the ice. One of the largest of the marginal lakes (*Lake Agassiz*) lay in the valley of the Red

River of the North (Fig. 187). This lake covered an area greater than that of all the Great Lakes. The water, however, was shallow. It came into existence when the edge of the retreating ice lay north of the lake, and blocked drainage in that direction. The water rose in the basin until it overflowed to the south, finally reaching the Mississippi River. When the ice at the north melted back far enough, a

Fig. 187. Map of extinct Lake Agassiz, and other glacial lakes. Lake Winnipeg occupies a part of the basin of Lake Agassiz. (U. S. Geol. Surv.)

new and lower outlet was opened to Hudson Bay, and the lake was drained. Lake Winnipeg and several smaller lakes may be regarded as remnants of Lake Agassiz, for they occupy the deepest parts of the old basin.

As late as 1870 the floor of extinct Lake Agassiz was almost unoccupied by farmers (Fig. 188), but during the next few years its soil was found to produce a fine grade of hard wheat, and a great tide of farm-seekers turned to the region (Fig. 189). On the nearly level lake floor it was possible to plow league-long furrows in straight lines, and later to do much of the work by such labor saving machines

as the steam plow. Ft. Gary quickly grew into the city of Winnipeg, and the wheat of the region helped to make Minneapolis the leading flour manufacturing city of the United States (p. 288).

The Great Lakes did not exist, so far as known, before the Glacial Period, but river valleys probably extended along their longer diameters. Lake basins were made as a result of (1) the deepening of these valleys by ice erosion, (2) the building up of the rims of the basins

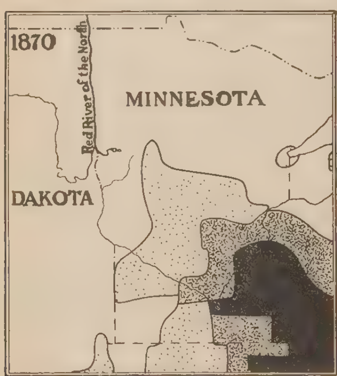


Fig. 188.

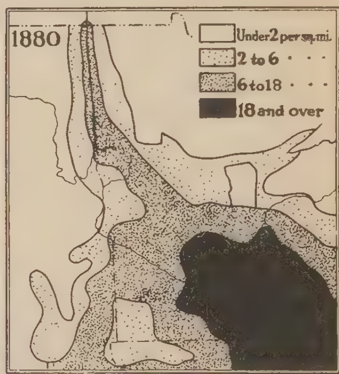


Fig. 189.

Fig. 188. Map showing distribution of population in region of Red River of the North in 1870.

Fig. 189. Population map of region of Red River of the North in 1880.

by the deposition of drift, and perhaps (3) the down-warping of the sites of the basins. The influence of the Great Lakes on climate and on certain industries has been noted in earlier connections. Their importance as commercial highways is considered in Chapter XVI.

Hundreds of the glacial lakes are of great benefit to man as pleasure and health resorts, and as sources of water supply. Many have become famous through their fine summer residences, and very many more are visited by numerous camping, boating, and fishing parties. In these ways the lakes have become large factors for good in the life of the people.

Effect of ice deposits on stream courses. The deposition of drift filled many of the former valleys. After the ice melted, the surface drainage followed the lowest lines open to it; but these lines did not always correspond with the former valleys, for some of the latter had been filled, and most of them were blocked up in some places.

The surface waters therefore followed former valleys in some cases, and in others flowed where there had been no valleys. In choosing their new courses, the streams in places ran down steep slopes or fell over cliffs. Many of the rapids and falls of the glaciated area, so important in the economic life of the country (p. 288), came into existence in this way.

Glacial soils. In the United States, glaciation increased the amount of mantle rock, and improved the quality of the soil in many places. Much of the latter is good because it is a thorough mixture of material derived from many kinds of rock, and so is well supplied with all the mineral elements necessary for plants (p. 169). It is instructive to compare Fig. 257, showing the relation of the improved acreage to the total farm acreage in the different states, with the map showing the glaciated area (Fig. 170). Iowa, Illinois, Indiana, and Ohio are seen to lead in the relative amount of their improved land. Glaciation is perhaps the most important fact in the geography of each of these states, and it has greatly furthered their high rank in agriculture.

Fig. 190. Map showing the glaciated (shaded) and unglaciated portions of Ohio.

The benefits which the states between the Ohio River and the Great Lakes received from glaciation may be illustrated further. Fig. 190 shows the glaciated and unglaciated parts of Ohio. The unglaciated part belongs to the Alleghany Plateau. It is in a mature stage of erosion, and the thin, sandy soils on the steep slopes wash easily. The first settlement in Ohio was made in this part of the state, at Marietta; but soon the tide of settlement set toward the more attractive glacial plains farther west and north, and the population of most of the unglaciated counties remained relatively sparse until the mineral resources of the region were developed. Many farmers in the unglaciated section turned their attention to sheep-raising when they found they could not grow grain for export in competition with the farms of the glaciated area, and grazing was long an important industry in the southeastern part of the state.

About four-fifths of Indiana were glaciated. On the average, the glaciated land is worth about twice as much as the unglaciated, and the yields of staple

crops bear a similar relation. The southern boundary of the region within which 4,500 bushels of corn are grown per square mile is the margin of the latest drift sheet. The situation is much the same in Illinois.

The quality of the soil in places was injured by glaciation. In some of these places the drift is very thin, while in others it is very stony, so that great labor is necessary to put it in workable condition. Again, the drift may be too sandy or gravelly to make good soil, or its surface may be too rough (pp. 173, 259).

Special uses of glacial deposits. Much drift clay ~~(rock-flour)~~ is used for making brick, tile, ~~and~~ other clay products. Ohio has been the leading state in the clay industry for many years, because of the abundance of raw clay, part of which is drift, cheap near-by fuel, excellent shipping facilities, and nearness to great markets. About 1,000,000,000 bricks are made from glacial clay each year in the vicinity of Chicago. The gravel of the drift is used extensively for road making, and in the manufacture of various kinds of cements.

DEPOSITS BY GLACIAL WATERS

Water flows in abundance from all glaciers in the summer, and from many glaciers all the time. Stream work, therefore, accompanies glaciation in all cases, and much of the drift left by ice is modified by water afterward.

Streams which flow from glaciers carry so much sediment that in many cases they build gravelly or sandy plains beyond the ice. Such a deposit in a valley below a glacier is a *valley train*. Valley trains are developed best just outside terminal moraines. The Rock River, in southern Wisconsin, filled its valley with gravel and sand to a depth of 300 to 400 feet just outside the terminal moraine of the last glacial epoch. The Columbia River filled its valley to the depth of 700 feet in places with sediment washed out from the ice. Since the ice-sheet melted, parts of most of the valley trains have been carried away, and their remnants are terraces (Fig. 162). Drift terraces are common features of many of the valleys of south-flowing rivers in the glaciated area and just south of it.

Streams which issue from an ice-sheet and fail to find valleys build alluvial fans. By growth, these fans may unite, making an *outwash plain*, very much like a compound alluvial fan. Like valley trains, outwash plains are developed best just outside the terminal moraines of ice-sheets, and their materials are stratified. East New York, Woodhaven, Jamaica, and other suburbs of Brooklyn grew up on the outwash plain of Long Island before the terminal moraine

just to the north was much settled. (What were the probable reasons for this?)

Deltas may be built in lakes at the ends or edges of glaciers, and the deposits made by waters beneath the ice and at its edge take on locally the form of ridges and hillocks.

As a glacier melts away, the waters produced by the melting flow over the surface of the drift which the ice had deposited, and modify it more or less by eroding in some places and depositing in others. As a result of all these phases of water work, much of the drift is stratified.

Summary. Although less important, ice takes its place with air and water as one of the three agents which modify land surfaces. From this standpoint, its principal mission is the wearing of the land and the moving of the waste toward the sea. Through their widespread effects on topography, soil, drainage, and the distribution of plant and animal life, the ancient ice-sheets are far more important than the glaciers of to-day, as factors in human affairs. Existing glaciers are valuable to man chiefly in connection with the development of power on the streams which flow from them.

QUESTIONS

1. In northern United States and Canada, would floods which occur as the river ice breaks up in spring be more likely to be disastrous on north-flowing or south-flowing streams? Why?

2. Why are there more glaciers in the Sierra Nevada and Cascade mountains than in the Rocky Mountains? Why are there more in Montana than in Colorado?

3. State all the factors which influence the size of a valley glacier.

4. Compare and contrast typical topographies due to (1) glaciation and (2) river erosion.

5. (1) What are all the important ways in which human interests have been (a) benefited and (b) injured by the work of the ancient ice-sheets in the United States? (2) *On the whole*, was glaciation beneficial or injurious?

6. Why are the effects of glaciation more favorable, from the standpoint of man, in northern United States than in northeastern Canada?

CHAPTER XVI

THE USES AND PROBLEMS OF INLAND WATERS

Many ways in which streams and lakes affect human interests have been noted in preceding pages. In the present chapter, inland waters are considered from the standpoints of navigation, power, irrigation, drainage, and water supply.

Navigation

In the early development of many countries, lack of roads led to the use of the waterways for trade and travel. Even after roads had been built, transportation by water was much cheaper than transportation by land in most cases, and traffic continued to use waterways where they were available. Where railroads have come into competition with waterways, the latter in most cases have lost much of their traffic. The waterways of some countries have been protected by law against ruinous railroad competition, and certain waterways, for example the Great Lakes, furnish such favorable conditions for transportation that their traffic has grown in spite of the railroads. The average cost of hauling over the railroads in the United States declined from $7\frac{1}{3}$ cents a ton per mile in 1837, to less than $\frac{4}{5}$ of a cent per mile in 1905; yet under favorable conditions, the cost of transportation by water is estimated to be only $\frac{1}{4}$ to $\frac{1}{3}$ that by rail. In 1909, rates for iron ore on the Great Lakes were less than one mill a ton per mile, while the rates for ore by rail were about one cent a ton for the same distance.

RIVER NAVIGATION

Streams were the first waterways to be used regularly for commerce. The Euphrates and Nile were among the rivers to which men first entrusted themselves and their goods. After a time, river navigation led to coastwise navigation, but to the end of the Mediæval Period there was little or no navigation of the open ocean. It is only in the Modern Period that navigation of the open sea has permitted the development of world-wide commerce.

Leading rivers of foreign lands. Because of its relief (p. 24), few of the rivers of Asia are important highways of commerce. The ~~Yang-tze is the greatest highway~~. Fed by the snow-fields of the mountains of Tibet, and flowing to the Pacific through some of the most densely populated provinces of China, it is both one of the longest rivers in the world, and one of the most important commercially. Large ocean steamers go up 600 miles to Hankow; smaller steamers ply the river 500 miles farther, to the mouth of the gorges; and native junks go up many miles more. The Hwang-ho, the other great river of China, flows through a densely settled region, but is nearly useless for navigation because of its shifting and silt-choked channel.

In India, the Ganges and Indus present a contrast similar to that of the Yang-tze and Hwang-ho. The Ganges traverses the most populous and wealthy provinces, and has been of great significance throughout the history of India. It is fed by many Himalayan torrents, and flows for about 1200 miles across the alluvial plains of the north. Ocean steamships ascend the Hugli, one of the mouths of the Ganges, to Calcutta, and the river is used more or less for navigation to the base of the mountains. The Indus River is used but little by steamers, because of many sand bars and frequent changes in the channel. Together with its larger tributaries, it is valuable chiefly for irrigation. The great rivers of Siberia are navigable for hundreds of miles, but their value is lessened because they flow to the Arctic Ocean.

The relief of Africa limits the navigation of most of its rivers to relatively short distances (p. 25). The Nile has regular steamboat service to the First Cataract, but navigation is not easy in the delta portion of the river below Cairo. Above the cataracts, the river is navigable throughout the year for long distances.

Throughout the history of Russia its rivers have been its chief highways. Even to-day, they have greater relative importance than the rivers of western Europe, because other means of transportation are less satisfactory; wagon roads are poor and railroads few. Most of the Russian rivers rise in the vicinity of the Valdai Hills and follow long courses across low, nearly level plains. Their currents, therefore, ordinarily are gentle. They are navigable throughout most of their courses, and the different systems have been joined by canals, so that there is water connection between the Caspian, Black, Baltic, and White seas. While the above conditions are

favorable to commerce, navigation of the Russian rivers is attended by serious drawbacks. They are ice-locked in winter (p. 246), subject to great floods in spring, affected by sand bars which hinder navigation at low stages, and most of them are tributary to inland seas. The Volga is the most important Russian river, and the largest river of Europe. Together with its tributaries, it is said to afford 7,500 miles of navigation. Its usefulness is lessened by the fact that its lower course is through a semi-arid region, and by the fact that it ends in a land-locked sea.

Most of the larger rivers of central and western Europe are important commercially, and large sums have been spent to improve them and extend their connections by canals. In Germany, river transportation increased more than fivefold in the thirty years preceding 1905, although Germany has a greater railroad mileage than any other country in Europe. This is in striking contrast with the situation in the United States (p. 278). The rivers and canals of Germany (p. 287) furnish from 8,000 to 10,000 miles of navigable waterways. So much work has been done in dredging, straightening, and otherwise improving the larger rivers, that it is said scarcely one of them flows in a natural channel.

The Rhine has influenced the history of Germany more than any other river, and is to-day the most important commercial river in Europe. Fed by melting snows in Switzerland and made steady in its flow by passing through Lake Constance, it flows through western Germany and the Netherlands, into the North Sea. Rotterdam, on the Rhine delta, is one of the greatest ports of continental Europe, and Cologne, though far inland, is practically a seaport. The fertile valley of the Rhine is settled densely. Commercially, the Elbe is the second river of Germany, though much less important than the Rhine. The traffic on these rivers is largely in heavy freight, such as coal and grain.

The Danube has been an important highway since early times. Like many other delta-building rivers, it was difficult to enter until jetties were built at its mouth. Extensive improvements have been made also at the "Iron Gate," and elsewhere. The Rhone is the largest river of France, and its valley is the natural highway into the country from the south. Navigation in the delta portion of the stream was hindered by shallow and shifting channels, and large sums have been spent in improvements. Even now, however, the Rhone is not navigable for large ships. The Po and the Ebro are the only other

European streams of importance flowing into the Mediterranean, and neither is used much for navigation.

In Great Britain, the rivers are comparatively short, but their value is increased by the fact that their lower courses are drowned, and subject to rather high tides. The tides help to make Liverpool and London great seaports, though both are on small rivers. Like the United States, Great Britain has neglected, till recently, the question of waterway improvement. To-day transportation in England is said to be the most expensive in Europe.

Fig. 191. Map showing principal streams in the United States actually used for purposes of transportation (1906). Only the parts so used appear on the map. (Data from map by U. S. Bureau of Corporations.)

The Amazon is the largest river in the world, with a length of about 4,000 miles. Ocean steamers can go up 1,000 miles, and with its 29 large tributaries it furnishes more than 20,000 miles of navigable water, most of it through dense forests. The river is used to carry out tropical woods, rubber, and other products. The Orinoco is navigable for small boats to within 100 miles of Bogota, and the La Plata System is navigated by steamers for long distances.

Besides the great rivers mentioned above, there are many others which serve as highways of trade and travel.

Navigable streams of the United States. There are about 300 streams in the United States that are navigated more or less (Fig.

191). Their total navigable length is about 26,400 miles — more than the circumference of the earth. Only a few have much commercial importance now, and many are used only by small boats engaged in local trade. As Fig. 191 shows, most of the navigable streams are in the eastern half of the country. The absence of navigable waterways (Why absent?) has been a serious disadvantage to much of the West.

The principal rivers, and the part which they have played in the development and commerce of the country, are discussed briefly in the following paragraphs. Most attention is given to the Mississippi System, because it is by far the most important.

Atlantic Rivers of United States

On the Atlantic slope there are nearly 150 streams navigable for varying distances from the sea — in most cases only to the head of tide-water. The rivers of New England are navigable for short distances only, because of falls and rapids.

The Connecticut is navigable to Hartford; the Merrimac to Haverhill; the Saco to Saco and Biddeford; the Kennebec to Augusta; and the Penobscot to Bangor. All these cities receive much freight by water. Many streams of central and northern New England are used for rafting lumber and floating logs.

Although the streams of New England afford little navigation, the larger valleys have been important highways since the settlement of the region began. They guided fur traders, lumbermen, and farmers (p. 219) into the interior. They served as lines of advance and retreat for Indian war parties and colonial armies. General Arnold invaded Canada in 1775 by way of the Kennebec and Chaudière valleys. To-day many of the valleys are followed by railroads. Boston was handicapped greatly in its commercial development by the fact that no large, navigable river came to it from the interior.

The Hudson is the most important, commercially, of the tributaries to the Atlantic from the United States. Because the Hudson Valley is drowned, deep water extends 100 miles inland, and the river is navigable 50 miles farther, to Troy.

The belt of relatively weak rocks along which the Hudson Valley developed contains, farther north, Lake Champlain and the Richelieu River. This long, narrow lowland, which extends from New York City to the St. Lawrence River near Montreal, was called by the Indians "The Grand Passway." General Burgoyne (1777) and General Prevost (1814) used it to invade the United States. When the Champlain Canal was opened between the Hudson River and Lake Champlain, water transportation was possible throughout its entire length. The Mohawk Valley and the low plain to which it leads furnish an easy route between the Hudson River and Lake Erie; the highest point is only 445 feet above sea-level.

Its drowned-valley harbor and good connection with the interior have been leading factors in the growth of New York City.

South of the Hudson River, most of the larger rivers are navigable to the "fall line," where the streams, in passing from the hard rocks of the Piedmont Plateau to the weak rocks of the Coastal Plain, have developed falls and rapids. Along this line are Philadelphia, Baltimore, Richmond, Petersburg, Raleigh, Columbia, Augusta, Macon, and Columbus (Fig. 192). Ocean-going vessels ascend the Delaware River to Philadelphia, and smaller boats go up to Trenton. Several drowned tributaries of Chesapeake Bay, itself a drowned valley, have some commercial importance.

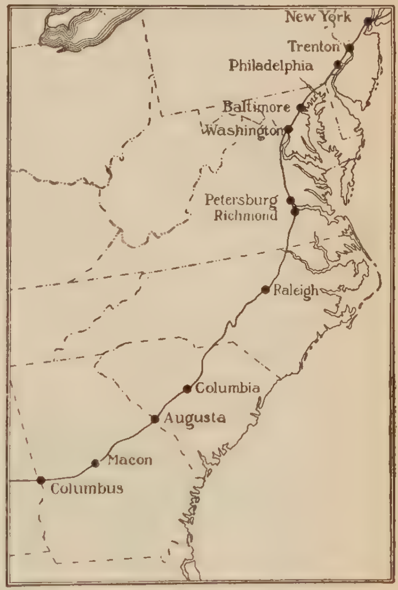


Fig. 192. Map showing leading cities along the "fall line."

The drowned streams of the Virginia region were deep enough for the light-draft boats of the colonial period, and served the settlers as roadways. The early plantations were arranged in narrow belts along the stream courses. For a century, travel in tidewater Virginia was largely by water; little attention was given to road building. Ships came from England direct to the wharves of many of the plantations, to exchange for tobacco the manufactured goods needed in the colony. Under these circumstances, no important collecting and distributing centers developed. To 1700, Jamestown was the only place worthy of being called a village. In South Carolina, the streams were not drowned sufficiently to render many of the smaller ones navigable. Hence Charleston became the commercial center of the colony, and soon also the social and political center. In general, freight rates decrease as the size of the cargo increases, and accordingly the tendency has been to build larger and larger boats. As a result, many of the streams of the Coastal Plain, once important in trade, were long since abandoned by commerce.

Mississippi River System

The Mississippi River has more than 50 tributaries that were navigated more or less in 1907. The navigable waters of the system aggregate nearly 14,000 miles and border or traverse 21 states.

The Mississippi River itself is navigable for large steamers to St. Louis, and for smaller boats to St. Paul. The Ohio River, now much the most important, commercially, in the United States, is navigable throughout its length. The Missouri River is navigable for small boats to Ft. Benton, in Montana, though it is now used but little. Other tributaries of the Mississippi are navigable for varying distances, as shown by Fig. 191.

Influence on early development of the West. At the close of the Revolutionary War, the Mississippi River was made the western boundary of the United States, and the supposed length of the river fixed the width (north and south) of the country at that time. It was an unsatisfactory international boundary line, for (1) its position shifts (p. 240), (2) the navigation of the river by the Americans from the east side and any foreign people from the west side would have led to friction, and (3) the river basin is a natural unit. The political unity of the Mississippi Basin was brought about by the Louisiana Purchase in 1803.

Fig. 193. A typical flatboat.

The early western settlers could send over the difficult mountain roads to the eastern seaports only valuable articles of little bulk and weight, such as whiskey, furs, and ginseng, or live stock, which could walk to market. For years, many thousands of hogs and cattle were driven over the mountains to Charleston, Baltimore, and Philadelphia, but salted and dried meats, flour, tobacco, and the other export products of the frontier had to go down the Mississippi River to New Orleans. Roads were few and poor, and the settler found it highly desirable to locate his farm within easy hauling distance of a navigable stream. The influence of navigable waterways upon the distribution of population is shown clearly by the census maps of 1820 (Fig. 278) and several later years.

One of the most used of the early boats on the western rivers was the *flatboat*, commonly 15 feet wide and 40 to 50 feet long (Fig. 193). While these boats served for downstream navigation, they were almost useless against the current of the Mississippi. Ordinarily they were broken up and the lumber sold at New Orleans. In these early days, freight was carried up-river largely in keel boats or barges. Most of them were equipped with oars, poles, and sails, and in many cases they were dragged upstream by men on the bank, tugging at a long rope. The average length of the trip from New Orleans to Louisville was three months, and in many cases it required four months.

Influence of steam navigation on the development of the Interior. The first steamboat appeared on the Ohio River in 1811, and within a few years it was seen that steamers could cope successfully with the currents of the rivers of the Interior, and that they would increase greatly the commercial value of the streams (Fig. 194).

Fig. 194. Mississippi River steamboats at New Orleans.

For a time, they could not be built fast enough to take care of the business. By 1850, the time involved in upstream travel had been reduced to about 1/18 of what it had been before the appearance of the steamboat. This meant, for example, that the steamboat brought New Orleans nearly as close to St. Paul, for certain purposes, as it had formerly been to Baton Rouge. In 1830 the cost of traveling by water from New Orleans to Pittsburgh was about ¼ what it

had been before the days of the steamboat. In general, the steamboat soon reduced freight charges to about 1/3 of what they had been, and finally to 1/4 and less. Because of these things, steamboat navigation became one of the greatest factors in the development of the Interior.

The population of the Interior, commercially dependent for the most part on the rivers, increased from 2½ millions in 1820 to 6⅓ millions in 1840. Probably no single factor contributed more than the steamboat to the rapid expansion of population during these years. Thousands settled along the tributaries of the Mississippi having steamboat service, and almost over-night river towns sprang up at favored points. The total value of the commerce of the western rivers in 1850 was estimated at $550,000,000.

The leading centers of steamboat trade. During the period of steamboat supremacy, the river commerce of the Interior centered largely in four cities — Pittsburgh, Cincinnati, St. Louis, and New Orleans.

For some time before the opening of the Erie Canal (1825, p. 286), Pittsburgh was the eastern gateway to the Mississippi Basin. Important roads connected it with the eastern seaboard. Its position at the junction of the Monongahela and Allegheny rivers gave it many advantages. The former brought coal from West Virginia, while the latter gave it command of the white pine of western New York. The principal products of the Pittsburgh mills reflected these advantages, together with the command of iron and the products of the surrounding farms. They were implements and machinery, iron ware, cabinet ware, lumber, furniture, flour, and liquors. These things were sent by river throughout the Interior.

Cincinnati had several marked advantages for the development of river trade. Situated midway on the Ohio and near the northernmost point of the great bend of the river, it was the nearest important river town for a large and fertile region north of the Ohio. It was also opposite the Licking Valley in Kentucky. The deep channel and favorable bank of the river along the city front made it easy to handle steamboat traffic. It was connected (in 1832) by canal with Lake Erie (Fig. 200). It received by river most of the implements and supplies, or the materials for their manufacture, needed by the tributary farming region. By river the city shipped the products of her flour mills, breweries, distilleries, and slaughtering and packing houses, which had been established to use the products

of the surrounding country. (Why was it desirable to manufacture these things near the points where the grain and animals were produced?) These advantages made Cincinnati the leading city of the Ohio Valley.

For years most of the capital and business enterprise of St. Louis were engaged in the river trade, though later the city became an important manufacturing point. The following were the chief advantages which made it, next to New Orleans, the greatest steamboat center on the Mississippi System. (1) It is situated near the mouths of the Missouri, Illinois, and Ohio rivers. (2) The Mississippi River is considerably deeper below St. Louis than above. At St. Louis, therefore, cargoes were exchanged between the lighter-draft boats of the river above and those of heavier draft plying on the river below.

Because of its commanding position near the mouth of the Mississippi River, New Orleans had for years the greatest commerce of any city west of the Appalachian Mountains. The population of New Orleans more than doubled between 1830 and 1840, in spite of the growing sand bars at the mouths of the river, frequent inundations, and disease (p. 243). No other important American city grew so fast. But even before the Civil War, the commerce and growth of New Orleans had received several serious blows. When canals were opened between the Great Lakes and the Ohio, Wabash, and Illinois rivers (p. 286), enormous quantities of goods from Ohio, Indiana, Illinois, and even from parts of Iowa and Missouri, went to the eastern markets by way of the Great Lakes and the Erie Canal, rather than to the southern markets. New Orleans particularly was injured as an importing city. It is some 1500 miles farther than New York from the cities of northwestern Europe, and the connection of New York with the Interior by way of the Hudson River, Erie Canal, and Great Lakes, was easier than that of New Orleans against the current of the Mississippi. The railroads continued the work of the canals, and made trade along east-west lines vastly greater than that along north-south lines.

In addition to the four cities mentioned, many smaller cities and villages depended largely on river trade. Such were Louisville, whose location was determined by the rapids of the Ohio River; Nashville and Kansas City, profiting commercially (Why?) from their respective positions on the great bends of the Cumberland and Missouri rivers; and Peoria, the leading city of the Illinois Valley.

Decline of river navigation. For years, commerce on the Mississippi River and its tributaries has been relatively small. The decline began at different times on different rivers — for example, in 1855 on the Illinois River, and about 1883 on the Yazoo River. The causes of the decline also differed somewhat, but the leading ones were of general application. (1) The channels of many of the rivers were shallow, crooked, and shifting. (2) The depth of water varied much from time to time, and from place to place. Boats suited best to the Great Lakes or coastwise trade could not be used on rivers or canals having but 6 feet of water, and boats giving the cheapest service for 6 foot channels could not be used in shallower waters, and so on. This was especially serious because of the importance of through traffic in American transportation. The great size of the United States and the contrasted products of its different parts mean that much freight must move long distances. (3) The use of the rivers forced freight in many cases to take roundabout courses. (4) The waterways in the central and northern parts of the country were closed by ice a part of each year (p. 246). (5) Water transportation was relatively slow. (6) In general, the methods, landing places, etc., of river and canal trade have remained unimproved since the Civil War, and have been less and less able to meet the demands of modern business. (7) When railroads were built throughout the Interior, these disadvantages proved fatal to river trade. The railroads at once got most of the passenger trade, and most of the traffic in perishable and expensive freight. The rivers could, and in the future can, hope to compete only in the transportation of heavy, bulky, and non-perishable commodities such as coal, grain, lumber, building stone, and the like. It is highly desirable that the navigation of the larger rivers be improved, so that they may help the railroads in transporting the ever-increasing quantities of cheap freight (p. 287).

Even since the loss of most of their business, many of the waterways have been of importance in regulating railroad freight rates. Most of the river towns that obtained good railroad connections did not suffer greatly from the decline of river trade; but to river towns without railroads the passing of the steamboat was a serious blow, and many such places decreased in population.

Present traffic. The Ohio and its tributaries now have the largest river trade in the country, and Pittsburgh is the leading inland city in the volume of its river commerce. The traffic is mainly in coal, lumber, logs, sand, and gravel. On the upper Mississippi, the

declining traffic is largely in rafted logs and lumber, and in sand. The principal things transported on the lower Mississippi are coal, lumber, crude petroleum (from Louisiana), and plantation products such as cotton, sugar, and rice.

In 1906, the total traffic for the entire Mississippi System, including rafts and harbor traffic, amounted to only about 30,000,000 tons. As in early days, most of the freight moves downstream.

Pacific Rivers of the United States

The rivers of the United States tributary to the Pacific Ocean have a combined navigable length of about 1,600 miles. None of them affords navigation far inland (Fig. 191), the San Joaquin and Sacramento rivers, especially, being nearly parallel with the coast. The Columbia is commercially the most important river of the Pacific coast. Ocean steamships reach Portland (some miles up the Willamette), 110 miles inland.

As the only river rising east of the Cascade-Sierra Nevada ranges and directly tributary to the Pacific Ocean, the Columbia was the key to political expansion on this portion of the coast. The fact that its branches approach closely the headwaters of the Saskatchewan and Missouri rivers, along which English and American explorers and fur traders advanced, was sufficient to cause a dispute between Great Britain and the United States over the Oregon country.

The Colorado River is navigable for light-draft boats in its lower course (Fig. 191), but is little used commercially.

COMMERCE OF THE GREAT LAKES

General features of the lakes. The Great Lakes are the most important inland waterways in the world. Their shore-line in the United States is more than 4,300 miles long, if all the minor irregularities are measured. They are connected by canals with the Atlantic Ocean and the Mississippi System (Fig. 200). Unfortunately, the shores of the Great Lakes have few naturally good harbors. Several of the leading cities and many of the villages on them had their locations determined chiefly by the mouths of creeks or rivers. Thus Buffalo was located in part by the mouth of Buffalo Creek, Cleveland by the mouth of the Cuyahoga River, and Chicago by the river of the same name. The entrances to these and similar streams were shallow, and easily choked by drifting sands. As a result, harbor improvements have been needed frequently throughout the history of the cities concerned.

The Great Lakes afford conditions for transportation in many ways vastly superior to those of the rivers, and their commerce has grown rapidly. The principal commodities carried on the Lakes are iron ore, coal, lumber, and grain — raw materials of great bulk, and not requiring rapid transportation. In 1910, the total domestic shipments on the Great Lakes amounted to more than 86,000,000 net tons, of which more than half was iron ore.

Early navigation. Apart from their use by the Indians, the Great Lakes were navigated first by the French from eastern Canada. Their fur traders navigated the Great Lakes in light canoes which could be used also on the streams leading to and from the Lakes, and could be carried over the many portages.

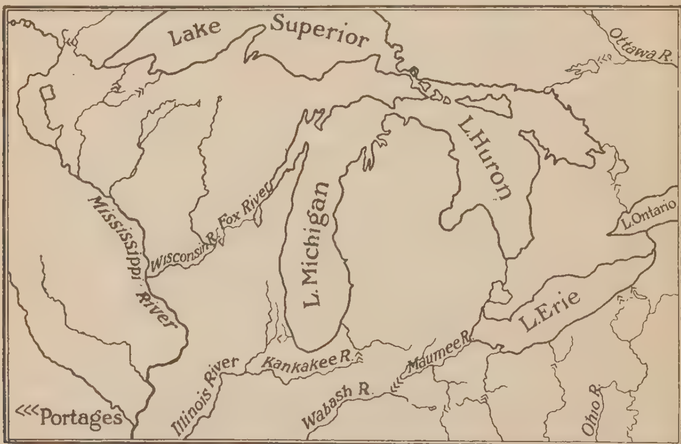


Fig. 195. Portages between the Great Lakes and the Mississippi System.

Most of the lines which the French used in passing back and forth through the Great Lakes region (Fig. 195) are still of importance in trade and travel. Canals were cut across several of the old portages (compare Figs. 195 and 200), and turnpikes and railroads followed the old lines or ran parallel to them. A number of villages and cities grew up at strategic points where the French had built forts to guard the lines of trade. Between Presque Isle (opposite the city of Erie, Fig. 251) and the Allegheny River, there ran at different times buffalo trail, Indian path, trader's trace, military road, turnpike, and railroad. A canal, soon abandoned, also once connected the city of Erie with the Ohio River. Long the favorite route of the French between the St. Lawrence River and the Great Lakes, the Ottawa Valley was followed by the Canadian Pacific Railroad westward from Montreal, and is to be followed by the projected Georgian Bay Ship Canal. In connection

with the latter much water power will be made available, and the Ottawa Valley probably will become one of the most important industrial sections of Canada. The above facts illustrate the truth of a statement that "trade and civilization in America have followed the arteries made by geology."

The first American sailing vessel appeared on the Great Lakes in 1797, but for a time the number increased slowly. In 1812 some half-dozen small schooners carried nearly all the traffic on Lake Erie, and for several years more the business of the upper lakes was limited to that of the fur-trading stations. Further development awaited the introduction of steam navigation, and the settlement of the neighboring lake and prairie plains.

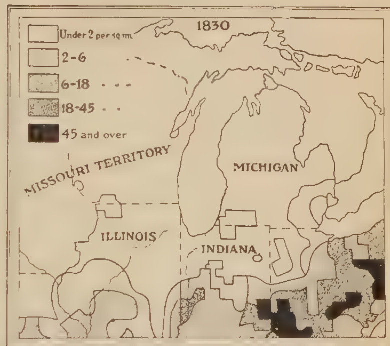


Fig. 196.

Fig. 197.

Fig. 196. Distribution of population in the Great Lakes region in 1830.

Fig. 197. Distribution of population in the Great Lakes region in 1850.

Steam navigation and the settlement of the Great Lakes region. Beginning in the decade 1820–1830 there was a large movement of population from New England and New York into the Lake region. For this there were many reasons, one of the most important being the great reduction in the expense and time involved in reaching the Interior, due to the opening of the Erie Canal in 1825 (p. 286) and the development of steam navigation on the western Lakes in the thirties. The first steamer appeared on Lake Ontario in 1816, but not till ten years later did one enter Lake Michigan, and not until 1832 did one visit Chicago. As the number of steamboats increased, passenger fares decreased, and it was soon possible to take household goods, farming implements, and stock into the Interior easily and cheaply.

A comparison of Figs. 196 and 197 will show how rapidly the northern parts of Ohio, Indiana, and Illinois, and the southern parts of Michigan and Wisconsin were settled between 1830 and 1850. During this period, also, Buffalo, Cleveland, Toledo, Milwaukee, and Chicago had their first substantial growth. They served as points of contact between the agricultural Interior and the manufacturing and commercial East. Their prosperity depended on commerce; not till later did they come to have large manufacturing interests.

The "Soo Canal" and the opening of Lake Superior. Before the "Soo Canal" was opened in 1855 there was little commerce on Lake Superior, and for the most part its shores were an unsettled wilderness. The canal opened the borders of the lake to settlement, and permitted the development of their natural resources, especially the iron ore (p. 179) and lumber. The value of the canal was increased greatly in 1881, when the first enlargement was completed. Between 1880 and 1890, the population of the Lake Superior counties of Michigan, Wisconsin, and Minnesota increased respectively 90 per cent, 400 per cent, and 800 per cent. The canal contributed greatly to this remarkable growth. In 1896, the canal was given a depth of 20 to 21 feet, and a further enlargement is now being made. There is also a Canadian canal around St. Mary's Falls.

In recent years about ⅔ of the total traffic of the Great Lakes has passed in or out of Lake Superior through the "Soo Canal." The tonnage passing through it during the seven months of the open season is about four times as great as that passing through the Suez Canal during the entire year. About 4/5 of the freight which passes through the "Soo Canal" is east-bound.

Traffic in iron ore and coal. In recent years the iron ore fields of the Lake Superior region have furnished about 4/5 of the output of iron for the whole country. Fig. 198 shows the movement of iron ore on the Great Lakes. Most of the ore goes to Lake Erie ports, and thence by rail to the Pittsburgh region. Most of the iron ore goes to the coal, rather than the coal to the iron, because the amount of coal needed in manufacturing steel is greater than the amount of iron ore, and because, where now manufactured, the steel is nearer its market than it would be if manufactured where the iron is mined. As Fig. 198 shows, much iron ore also goes to the iron and steel centers near the head of Lake Michigan, especially to South Chicago and Gary, Indiana. At these points Indiana and Illinois coal (see Fig. 85) may be obtained cheaply, and they are close to great markets.

Many boats which bring iron ore, lumber, and grain to the eastern lake ports take back coal at very low rates. This has helped to make possible the recent establishment of the iron and steel industry at the western end of Lake Superior. It also means cheap

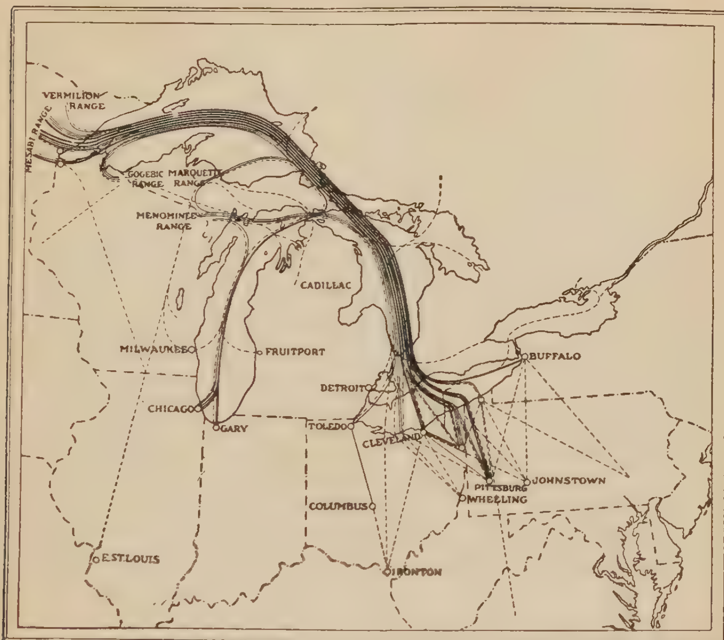


Fig. 198. Map showing movement of iron ore on the Great Lakes in 1909. (After Birkinbine.)

coal in the region west of Lakes Michigan and Superior, which is without coal resources of its own.

Lumber trade of the lakes. The western end of the great northern forest of pine, spruce, hemlock, cedar, fir, birch, etc., lies in Michigan, Wisconsin, and Minnesota (Fig. 271). Lumbering began in Michigan in the early thirties, and spread westward and northward. Production increased rapidly after 1850, and for many years the Lake states were the most important lumber district in the United States, furnishing, in 1880, ⅓ of the total output of the country. Logs cut in the interior were floated down the streams to the Lakes. At the mouths of the larger rivers busy towns developed

where the logs were manufactured into lumber. First from the mill towns of eastern Michigan, and later from more distant points, the manufactured lumber was shipped at low lake rates to Detroit and the cities of Lake Erie. Most of the products of the Lake Michigan mills were sent through Chicago to the prairies, the settlement of which created a demand for enormous quantities of building and fence material. As the pine forests near the Lakes and along the larger rivers flowing into them were cut away, mill towns sprang up in the interior, from which more and more lumber and lumber

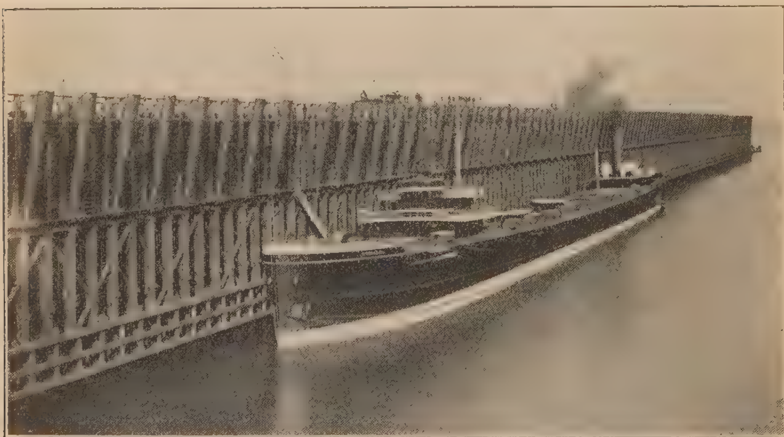


Fig. 199. Loading ore at Escanaba. (Copyright by Detroit Publishing Co.)

products have been sent to market by rail. This change and the general decline of the lumber industry in the Lake region since 1890 (p. 372), due to the cutting away of the forests, have reduced greatly the lumber trade of the Great Lakes. In 1910, 1,208,000 thousand feet of lumber were transported on the Lakes.

Movement of grain and flour. The transportation of grain and flour has been an important phase of commerce on the Great Lakes ever since the settlement of the Lake states. The movement is almost entirely from the south end of Lake Michigan and the west end of Lake Superior, to the east end of Lake Erie (Why?).

Modern lake vessels. Much of the freight on the Great Lakes is carried in steel freighters, built for speed, capacity, and strength (Fig. 199). Many are 500 to 600 feet long, and have a capacity of 10,000 to 12,000 tons. One of the largest carried 13,000 tons of

soft coal in a single cargo, and on another occasion 422,000 bushels of wheat. Another lake vessel transported more than 323,000 tons of iron ore in 27 cargoes during the season of 1907.

CANALS

General considerations. The first canal in the United States was opened in 1794, but there were few of importance until the successful completion of the Erie Canal (1825) aroused general interest in canals. The period of most active canal digging extended from 1825 to 1837. Altogether, about 4,500 miles of canals have been constructed in the United States (Fig. 200). Most of them extended and supplemented natural waterways. The more important ones were of three classes: (1) Those along the Atlantic coast, connecting bays or rivers between which the natural water routes involved much greater distances. (2) Those connecting, or begun with the intention of connecting, the leading Atlantic seaports with the Ohio River or the Great Lakes. (3) Those connecting the Great Lakes with the Mississippi System. As Fig. 200 shows, many feeders were built for the main canals.

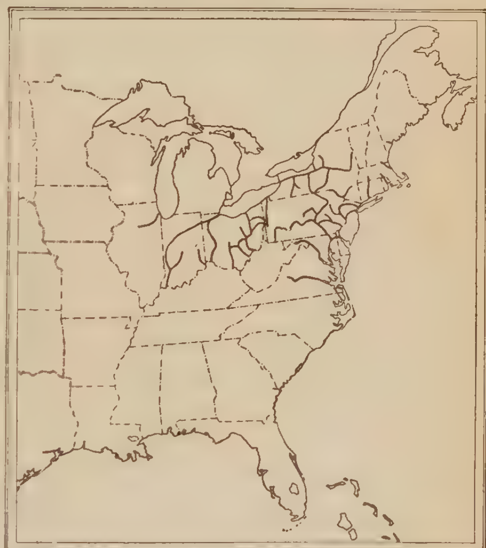


Fig. 200. Map showing principal canals constructed in the United States. Most of them are no longer used.

Of the 4,500 miles of canals constructed, nearly 2,500 miles, costing about $80,000,000, have been abandoned. Most of the conditions which contributed to the decline of river navigation (p. 278) contributed even more to the decline of the canals. They were all shallow, and the canal boats were therefore of small capacity; many of the canals varied in size in their different parts, retarding

through traffic. Most of the canal boats were towed by animals. Some of the canals were located unwisely, some were managed badly, and most of them fell an easy prey to railroad competition.

The Erie Canal. The Erie Canal, connecting the Hudson River with Lake Erie at Buffalo (Fig. 200), was built by New York to control the trade of the central and western parts of that state, as well as to gain the trade of the Great Lakes region, toward which settlement was setting. Some of the products of the former sections were going down the Delaware and Susquehanna rivers to Philadelphia and Baltimore, and some were seeking the Canadian markets along the St. Lawrence River. Such a canal was needed also for military reasons. In the event of another war along the northern frontier, some way better than any existing during the War of 1812 was needed to get supplies to the shores of the Lakes.

The canal became a great highway of expansion into the Interior, and a great outlet for surplus western products; it caused the rapid growth of Buffalo, Rochester, and other places along its course; it increased land values throughout the region tributary to it; and it helped to transform New York City from a market town for the Hudson Valley into the leading commercial city of the continent. The cost of transportation between Albany and Buffalo fell from $88 to $5.98 a ton in the twenty-six years after the opening of the canal. The tolls collected on the canal paid for its construction in 10 years.

Until the late 1860's, the Erie Canal was the most important transportation route between the Great Lakes and the Atlantic Ocean. In 1866, the freight carried by the canal was 60 per cent of that moved across New York. Soon after this it began to decrease, and the tonnage on the canal has been small for years. The people of New York voted in 1903 to spend $101,000,000 in improving the canal, and this work is now in progress.

Canals between Great Lakes and Mississippi System. It is impracticable to consider here, one by one, the different canals which connected the Great Lakes with the Ohio and Mississippi rivers (Fig. 200). In general, they injured the cities and trade of the Mississippi River (p. 277), and benefited greatly the cities and commerce of the Great Lakes. For a time, most of them were powerful factors in the development of the sections which they crossed. In addition to giving special benefits in different cases, they cheapened transportation, opened new markets, raised the prices of

farm products, lowered the cost of imported merchandise, increased land values, stimulated the growth of population, and helped build up towns and cities. Some of these canals have been abandoned, and for years the rest have been used but little.

Foreign canals. Several foreign countries have systems of canals suited to modern conditions of transportation. This is true particularly of Germany. One of the important canals of Germany (the Kiel Canal) was built to permit ships to pass between the Baltic and North seas without going around Denmark. The Manchester Ship Canal allows ocean-going ships to reach the docks of Manchester from Liverpool.

IMPROVEMENT OF AMERICAN WATERWAYS

Why waterways should be improved. The larger rivers of the United States should be so improved as to make possible economical transportation upon them. This is desirable because (1) water transportation is normally cheaper than rail transportation, and if the cost of transportation is reduced, the price to the consumer of the things transported will tend to be lower; (2) waterways tend to keep down the rates of competing railroads; and (3) in recent prosperous years the railroads have been unable to handle promptly the traffic of the country during the busy season. The products and trade of large sections of the country are increasing much faster than the transportation facilities of the railroads.

Leading improvements needed. Among the projected improvements are: (1) A deep canal (at least 20 feet) between the Hudson River and the Great Lakes. The new Erie Canal (p. 286) will have a depth of 12 feet. (2) A deep inner waterway along the Atlantic coast from New England to Florida, connecting various bays and sounds. (3) A deep waterway between Lake Michigan and the Gulf of Mexico. This involves extending the Chicago Sanitary and Ship Canal (built primarily to dispose of the sewage of Chicago) to the head of navigation on the Illinois River, and improving the Illinois and Mississippi rivers. Such a waterway would be of great importance to the trade between the northern and southern parts of the Interior, and, following the opening of the Panama Canal (p. 355), to the trade of the northern Interior with the Pacific coast, and with foreign countries both to the south and across the Pacific Ocean. (4) A canal to connect Puget Sound and the Columbia River.

Water Power

Use in the past in United States. Water power has located many manufacturing cities in the United States, and contributed largely to their growth. It was used first in a large way in New England, where it is one of the leading natural resources. Bellows Falls, Holyoke, Manchester, Lowell, Berlin, Biddeford, Lewiston, Rumford Falls, Augusta, and Bath are among the busy industrial centers created largely by water power. There are also many water power cities farther west. Grand Rapids, Michigan, a leading furniture manufacturing center, is an example. Located 40 miles inland, at the rapids of the Grand River, its first lumber mills were at a disadvantage compared with those on the shores of the Lakes (p. 283; Why?). As a result, cabinet shops and furniture factories were soon established. (What was gained by doing this?) The power afforded by the river was soon outgrown, and the timber supply in the vicinity exhausted, but the advantages of an early start, and of established plants with world-wide reputations for furniture of superior quality, keep the city to the front. Similarly, St. Anthony's Falls and command of the forests and wheat-fields of Minnesota made Minneapolis an important manufacturing city. Nearly $^1/_{10}$ of the flour and grist mill-products of the country are manufactured there.

Water power formerly had certain disadvantages, because the mills using it had to be close to the source of the power. Coal was abundant, cheap, and easily shipped, and was used more and more for manufacturing purposes. Water power continued to be used most in connection with long-established industries, and in connection with industries demanding special conditions, such as the manufacture of paper and wood-pulp.

Present conditions and future importance. In recent years there has been a great increase in the use of water power in the United States. In 1900, less than 1,500,000 horse power were developed from water, and in 1908 more than 5,350,000 horse power. This change has been due largely to the following conditions, which also will help to bring about an increasing use of water power in the future: (1) There have been rapid developments in the transmission of energy in the form of electricity. Electric power developed by falls and rapids (*hydro-electric* power) is transmitted some 300 miles by a Colorado company. On the basis of transmission for 200 miles, a water power could, if sufficient, serve an area of 125,000 square miles.

In the future, few places in the United States will be beyond the reach of hydro-electric power. Power from Niagara Falls now runs street cars, lights buildings, and is furnished very cheaply for manufacturing purposes in Buffalo and other cities as far away as Utica. On the Canadian side, it is carried to various cities and villages as far away as the Detroit River. Snoqualmie Falls, Washington, furnish power for electric lights, street railways, motors, etc., in Seattle and Tacoma, some 50 miles distant. (2) In some ways, electric power is better than other kinds for large plants, and it also has a great advantage over other forms of power in that it may be carried economically to the small user. (3) In many places, hydro-electric power is even now cheaper than power obtained from coal.

It is estimated that about 3/5 of the power now developed from coal in the United States could be developed cheaper by water. Furthermore, the substitution would lengthen greatly the duration of the coal supply (p. 177).

As the supply of coal diminishes and its cost increases, electricity developed by water will be used more and more for transportation, lighting purposes, and manufacturing. Doubtless the time is not distant when most railroads, street cars, and interurban lines will be operated in this way. In time, nearly all manufacturing industries will depend largely on water power, and it is fortunate indeed for the future of the United States that its available water power is so great.

Amount and distribution of water power in the United States. In view of the part which water power is to play in the life of the nation, its amount and distribution are matters of great interest and importance. The total amount has been estimated on several bases. (1) If the amount of water available in the streams during the two weeks of lowest water were used throughout the year, and if all above that amount escaped unused, about 37,000,000 horse power could be developed. This is called the *primary* horse power. (2) If plants were established to develop the minimum power available for the six high-water months, there would be about 66,500,000 horse power per year. (3) If the flood waters were stored in reservoirs, so that the streams were utilized fully, there could be developed between 100,000,000 and 200,000,000 horse power. The meaning of these figures is realized best when it is remembered that now about 26,000,000 horse power are developed from coal, and only about 5,500,000 from water. The estimated distribution of water power throughout the country on the first two bases given above is shown in the table on the next page.

ESTIMATE OF WATER POWER IN THE UNITED STATES

Principal Drainages	Horse Power Available: Primary or Minimum	Horse Power Available: Minimum of the Six Highest Months
Northern Atlantic to Cape Henry, Va	1,702,000	3,186,600
Southern Atlantic to Cape Sable, Fla	1,253,000	1,957,800
Eastern Gulf of Mexico to Mississippi River	559,000	963,000
Western Gulf of Mexico, west of Vermilion River	433,766	822,650
Mississippi River, main stream	147,000	335,000
Mississippi River tributaries from east	2,472,590	4,940,300
Mississippi River tributaries from west, including Vermilion River	3,948,970	7,085,000
St. Lawrence River to Canadian Line	6,682,480	8,090,060
Colorado River, above Yuma, Ariz	2,918,500	5,546,000
Southern Pacific to Point Bonita, Cal	3,215,400	7,808,300
Northern Pacific	12,979,700	24,701,000
Great Basin	518,000	801,000
Hudson Bay	75,800	212,600
Total	36,906,200	66,449,310

Improving water powers. It is highly desirable that power streams should maintain a relatively even flow. If a stream can develop 5,000 horse power during brief flood stages, and only 500 horse power the rest of the time, not much more than the latter amount can be used, and the rest is lost. Forests about the head-waters of mountain streams and systems of reservoirs hold back the storm-waters and tend to keep the flow of streams steady. They are therefore important to manufacturing, as well as to navigation and farming (pp. 166-169, 221-222).

Water power in other countries. Water power is afforded by most large streams in mountain regions, and by many youthful streams in other regions, especially those that have been glaciated recently. In Europe, Switzerland is likely to be the first country to utilize fully its large water power resources. The streams of Scandinavia, Austria-Hungary, France, Italy, and Germany also afford much power. Enormous power could be developed from the streams of the Caucasus and Himalaya mountains, but this is not likely to be done in the near future. Considerable power may be obtained from the streams of eastern Australia. Canada has an abundance of water power, both in the western mountains and in the eastern part of the country. In the latter section, it is due largely to glaciation. Many other countries have more or less water power, much of which will be of value to man sometime, if not so now.

Irrigation

Irrigation means the artificial application of water to land for the benefit of plants. It is practiced in many dry regions because otherwise crops cannot be grown, and it is being introduced more and more into humid regions, in order to increase the yield of crops. Even in eastern United States, there is scarcely a year when some crops do not suffer from lack of rain, and there are occasional years of serious droughts.

The common statement that farming without irrigation cannot be carried on successfully where the annual rainfall is less than twenty inches is very misleading. The development of "dry farming" (p. 329) and the introduction of drought-resisting plants (p. 173) are changing some semi-arid regions into fairly productive farm lands, without irrigation. Again, much depends on the distribution of the rainfall. If it came just when the plants needed it, ten or twelve inches would suffice to grow many staple crops by ordinary methods of farming. The yields that would be obtained under such conditions could be increased greatly, however, by irrigation.

Practiced since ancient times. Irrigation was practiced in Egypt 2,000 years before Christ, and probably much earlier, but the area irrigated then was much less than now. About 6,000,000 acres have been irrigated in Egypt in recent years. The ancient civilizations which existed in Mesopotamia were made possible by extensive systems of irrigation. The ditches of the region have long been unused, and much land which once was cultivated is now waste. The English government has extended irrigation in India until about 50,000,000 acres are so watered.

IRRIGATION IN WESTERN UNITED STATES

Irrigation was practiced first in the United States in Arizona and New Mexico. In the latter, there are ditches said to have been used continuously for 300 years by people of mixed Spanish and Indian descent. The Mormons were the first Americans (except Indians) to irrigate systematically. The conditions for irrigation were ideal on the slopes of alluvium at the base of the Wasatch Mountains, and without irrigation they could not have been cultivated. Irrigation by Americans in the Salt River Valley of Arizona began in 1867, and in southern California a few years later.

Value of irrigated land. Irrigation changes unproductive, worthless, or nearly worthless land into land producing more than the average farm land in eastern United States. (Compare Figs.

Fig. 201. The Yakima desert before irrigation. Near North Yakima Washington. (U. S. Reclamation Service.)

Fig. 202. The region shown in Fig. 201, after irrigation. (U. S. Reclamation Service.)

201 and 202.) Irrigated lands are worth $100 or $150 an acre for general farming purposes, and choice fruit lands with good orchards are worth $1,000 or more an acre. In general, the great value of much of the irrigated land is due to the following: (1) The soil of arid regions is likely to be rich in mineral plant foods, because for ages ground-waters have come to the surface through capillary action, and as they evaporated into the dry air they have deposited in the soil the mineral matter dissolved during their journey under-ground (p. 212). In some cases when irrigating waters have been turned on the land it has been found that so much of certain materials (alkaline salts or "alkali") had accumulated in this way in the soil, that plants would not thrive until the alkali was partly leached out. (2) Irrigated soils, when used rightly, are durable, for soil wash can be avoided largely, and the store of soluble mineral matter in the sub-soil is large. (3) Irrigating waters contain fertilizing matter in solution. (4) Irrigated crops, if properly cared for, get just the amount of water needed at just the time they need it. (5) In the warmer sections of the West, several crops a year may be grown.

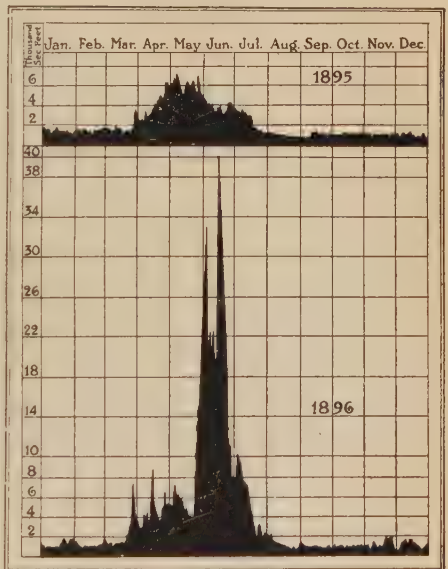


Fig. 203. Diagram showing discharge of the Boise River above Boise, Idaho, in 1895 and 1896. (Newell, U. S. Geol. Surv.)

Area of irrigable land. As the demand for land increases with the population, it will be advisable to extend irrigation to the utmost limit. It is estimated that about 45,000,000 acres (an area the size of Missouri) are irrigable. This is only about 5 per cent of the entire arid region. The chief factors which will control the area which can be irrigated are matters of topography and rainfall. (1) The water supply comes largely from rain and snow falling on the mountains,

and the mountain catchment areas are comparatively small. Furthermore, only a small fraction of the rainfall of the arid region can be made available for irrigation (Why?). (2) The volume of many of the western rivers varies greatly (Why? Fig. 203), and in many cases it is necessary to build dams to hold the flood waters in reservoirs, so that they may be let out as needed during the growing season. Unfortunately, there are comparatively few places suited for the storage of large amounts of water, and in some cases where there are good sites for dams, the areas tributary to them furnish little water. (3) In many places the ground is so rough that the water cannot be spread over it properly. (4) In many places the possible crops probably would not justify the expense of getting the water on the land. (5) The area which can be irrigated depends in part upon the amount of water per acre required for crops. In the case of the government projects (p. 295), this varies from 1½ to 5½ acre-feet[1] per year. (Apart from the fact that some crops require more water than others, why should the variation be so great?)

Fig. 204. A canal lined with cement. Truckee-Carson Project, Nevada. (U. S. Reclamation Service.)

There are several reasons for hoping that the irrigable areas may prove larger than stated above. (1) Many fields are now poorly prepared for the water, so that it spreads unevenly, and more is required than would be if the land were less uneven. With the land better prepared, the water could be spread over a larger area. (2) Much more land could be watered if loss by seepage from the canals were not so great. This now amounts, on the average, to about 25 per cent of the water. The loss probably will be reduced more

[1]An acre-foot of water is the amount which would cover an acre of ground to the depth of one foot.

and more by lining the canals with cement (Fig. 204). (3) The loss of water by evaporation from the canals also will be reduced. (4) Many irrigators now use much more water than is necessary to secure the largest returns. This will be corrected by legislation, and by increasing intelligence on the part of the farmers. (5) Measurements to determine the amount of available water have been made

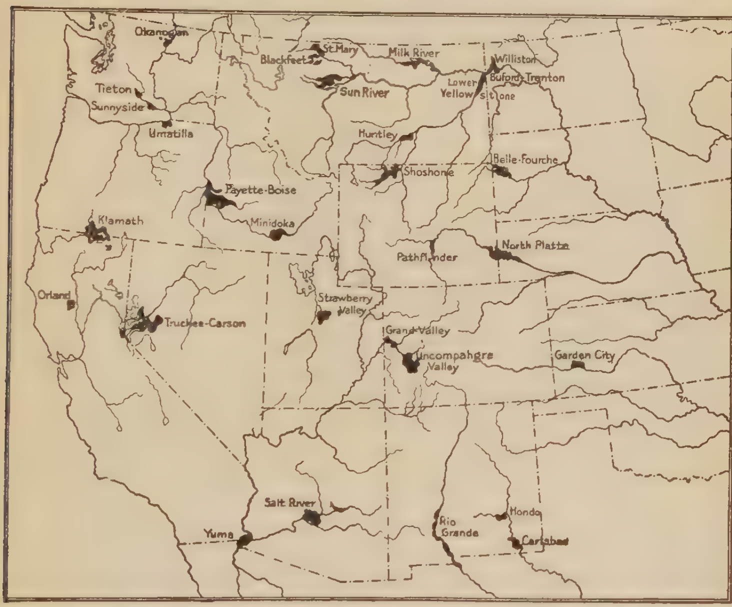


Fig. 205. Map showing Government irrigation projects.

on only a part of the western streams, and on most of these the records cover only a few years. Further work along this line may show that the streams can furnish more water than is now supposed. (6) For much of the West detailed topographic surveys have not been made, and they may add new possibilities.

Government projects. Irrigation was begun in the West by individual settlers, who led water to their fields from small rivers and creeks through ditches which they dug. Co-operation was necessary, however, before extensive areas could be watered. This has been brought about in various ways. Many so-called "irrigation districts" have been organized to reclaim arid land under state laws. Since

1894, much land has been reclaimed, especially in Idaho and Wyoming, under the Carey Act, which provides for irrigation through co-operation by the nation, state, corporations, and settlers. While much was being accomplished in these ways, it became evident that the federal government must itself undertake those projects that were too expensive, too large, or too slow in producing returns, to tempt individuals or companies. Hence Congress passed the National Reclamation Act in 1902. This act provides that money derived from the sale of public lands in the arid states shall constitute a reclamation fund. The cost of any given project is assessed against the land benefited, and is paid by the settlers in ten equal annual payments. The moneys returned to the government, together with the proceeds of the sale of other lands, are used again for further reclamation.

Fig. 206. Site of the great dam on the Shoshone River, in Wyoming.

There are some thirty government projects under way (Fig. 205), which, when finished, will irrigate more than 3,000,000 acres. The average cost to the settler probably will be $40.00 to $50.00 per irrigated acre. The success of these great projects of the government has stimulated private enterprise greatly.

A few facts concerning some of the government projects will illustrate the scope of the work. The Salt River Project (Arizona) has the recently completed Roosevelt dam, 280 feet high and 1080 feet long on top. This dam forms a lake covering 16,320 acres. The power developed by the water as it comes out is used to pump groundwater to irrigate more land, for lighting purposes, and in other ways. The storage dam for the Rio Grande Project is one of the largest in the world. It will make a lake 40 miles long, covering 40,000 acres, and containing 2,600,000 acre-feet of water. The water for the Truckee-Carson Project (Nevada) is stored in Lake Tahoe, a glacial lake in the Sierra Nevada Mountains. From Truckee River, the out-

let of the lake, it is diverted into a canal and carried across to the Carson Valley to reclaim land formerly composed largely of sand dunes and alkali flats. Nearly half the area of the Klamath Project (California-Oregon) is occupied by swamps and lakes, so that it must be drained before it can be tilled. After being drained, it will need to be irrigated. The water supply for the Shoshone Project, in northern Wyoming, is derived from the Shoshone River. To regulate the flow of this river, the government has built a dam 328½ feet in height (Fig. 206), the highest structure of the kind ever built.

Crops of the irrigated lands. Many different crops are grown on the irrigated lands, for the conditions affecting plant life vary greatly. Alfalfa and sugar beets are produced in many places. Hay, grain, and vegetables are staple products in Montana and Wyoming. In addition to these things, fruits are grown extensively in Idaho, Washington, Oregon, and Colorado. The great citrus fruit region is in southern California, and the raising of these fruits has increased rapidly in recent years. In 1910–11, nearly 18,000,000 boxes of oranges and lemons were shipped. The growing of deciduous fruits (peaches, pears, and the like) also has become of great importance in California, as in various other sections of the West. The shipping of these fruits in large quantities to distant markets has been made possible by the development of the refrigerator car, in which most of the shipments from California are made. In the extreme southwest, the leading products are semi-tropical fruits, cereals, and alfalfa.

Population capacity of the irrigated lands. The high value of the irrigated lands encourages methods of tillage which secure maximum yields from minimum areas, and, together with the difficulty of hiring effective labor in the West, leads to small farms. In orchard regions, 5 to 10 acre holdings are common. On a number of the government projects, the farm unit has been fixed at forty acres. These things mean a dense rural population. The ultimate population of the irrigated lands probably will be not far from one person to an acre.

Farm villages. In many ways, social conditions promise to be nearly ideal in most of the irrigated districts. The small farms will make it possible for many of the farmers to live in town, going to and from their land daily. It seems probable that each 5,000 or 6,000 acres of cultivated land will support a farm village, where the farmers will have the advantage of graded schools, public libraries, etc. On a number of the government projects, the Reclamation Serv-

ice has laid out town sites about six miles apart, and set aside lots for churches, schools, and cemeteries. The town lots are sold to the highest bidders, the proceeds going to the Reclamation Fund. Irrigation promises to create many small villages, rather than a few large cities.

Irrigation and the National Forests. From the standpoint of irrigation, as well as of navigation and water power, it is highly important that the flow of the streams be uniform. The preservation of forests about the headwaters of the streams helps to bring about a more even flow of water, and partly for this reason the National Forests were established (Fig. 207). Outside Alaska, these forest reserves have an area (1912) of about 144,000,000 acres. They are cared for by the Forestry Bureau of the Department of Agriculture.

IRRIGATION IN THE HUMID STATES

Present situation. Irrigation is practiced in some of the humid states in growing certain crops. For example, water is pumped from wells on to the land at various points on the coastal plain between New Jersey and Florida, to irrigate truck farms. In the latter state, irrigation has been undertaken recently on a rather large scale. This is particularly interesting, since all parts of Florida receive more than 50 inches of rain a year, and some parts more than 60 inches. But much of the soil does not retain moisture well, evaporation is great, and the fruit groves and truck farms are benefited by watering during the drier season. Their products are so valuable that even a partial crop failure means heavy losses. Irrigation is practiced extensively on the rice-fields of Louisiana, Texas, and the Carolinas.

As yet, irrigation in the East is restricted largely to special crops which warrant relatively large expenditures, such as strawberries, raspberries, blackberries and other fruits, and certain vegetables. With these crops, a small or imperfect yield because of drought is disastrous.

Future importance. It has been estimated that the yield of every important crop of eastern United States could be doubled by irrigation. It is therefore certain to be practiced more and more in the future, as the population increases and the demand for food grows. As in the West, the irrigator can apply just the amount of water needed at just the time required, and he can grow many more plants on an acre than otherwise.

Fig. 207. Map showing distribution of the National Forests (1910).

Reclamation of Swamp and Overflowed Lands

WET LANDS OF THE UNITED STATES

The reclamation of swamp and lake areas has been referred to incidentally in other connections (pp. 171, 241, 242, 262). The matter is summarized briefly here.

Area and distribution. It is estimated that the total area of swamp land in the United States is about 79,000,000 acres, most of which can be reclaimed ultimately. Swamp lands occur in many states, but the largest areas are in the states containing (1) the Atlantic and Gulf coastal plains, (2) the flood-plains of the Mississippi River and its larger tributaries, and (3) the area covered by the last ice-sheet. About half of all the area of swamp land is in Florida, Louisiana, Mississippi, and Arkansas.

Status and cost of reclamation. It is estimated that nearly 16,000,000 acres have been drained, mostly in the northern interior states. In most other parts of the United States, the problem of draining wet lands received little attention until the last few years. This was due to the abundance, till recently, of good land not requiring drainage. Progress is now being made in Florida, Louisiana (p. 171), and other states.

The cost of reclamation varies with the character of the swamp, the methods employed, and the machinery used, from $3 or so an acre, to $30 or more. In some cases ditches to carry off the water are all that is needed, and the cost is then slight; in other cases tile-draining is necessary, and then the cost depends largely on the character of the land. Along many rivers and coasts it is necessary to build dikes. The water of the swamps is then brought to certain points by drains or ditches, and pumped out over the dikes. In many such cases, rather large areas are treated as units, and improvements in methods and machinery have reduced the cost one-half in the last 15 years. The average cost of drainage has been estimated at $15 an acre. This is much less than the average cost of irrigating dry lands (p. 296).

Results of reclamation. (1) The soils of most reclaimed swamp lands are very fertile. Since most swamp areas are of little use, it is clear that drainage greatly increases their value.

The value of drained farming land varies from $20 or less an acre, to $500 and more. It depends largely on the character of the soil, the climate, transportation facilities, nearness to or distance from good markets, etc. It has been

estimated that, when drained, the swamp lands of the United States will have an average value of $60 an acre. Their present value has been estimated at $8 an acre.

(2) The products of the drained lands will increase greatly the crops of the country, and will feed and support millions of people.

(3) An immediate effect of the systematic draining of the swamp lands will be to increase the healthfulness of the areas concerned. The principal breeding places of malaria-carrying mosquitoes will be destroyed, and that disease practically stamped out. The present annual loss to the country from malaria, due to the reduced efficiency of the sufferers, the losses to business in the areas affected, etc., has been estimated at $100,000,000.

Reclamation of lake-covered lands. Swamps merge into lakes, and many so-called lakes doubtless are included in the estimate of swamp areas already given. Ultimately, most shallow ponds and lakes will be drained. It will always be impracticable to drain some lakes, and many others will be carefully protected and preserved (p. 264).

WET LANDS OF OTHER COUNTRIES

Large areas of wet land have been reclaimed in Europe. Much land now farmed in Holland was won from the sea. About 1/3 of England was marsh or bog land in the reign of Alfred the Great (871–901). Probably "not far from 1/20 of the tillable land in Europe was inundated and unfit for agriculture in the eighth century of our era."

Vast areas of swamp land in various tropical countries probably will remain in their present condition for a long time.

Water Supply

Apart from its support of plant and animal life, the most important use of water is for home and city purposes — that is for drinking, bathing, and various household purposes, for sprinkling streets, flushing sewers, for fire protection, manufacturing, and the like. It is estimated that between 50 and 150 gallons of water per person are used daily in the cities of the United States. Of this, about half a gallon per person is used for drinking.

Sources of water supply. (1) Rain-water, stored in cisterns and "tanks," is used extensively for drinking in the arid states, and for other purposes throughout much of the country. (2) Most of the country people of the United States obtain water for domestic purposes from underground, through ordinary wells and springs; but

no large city could get water enough in this way. Thousands of wells and springs have failed in recent years because the water table (p. 205) has been lowered by unwise farming and deforestation (p. 208). (3) In the Atlantic Coastal Plain, the Great Plains, and some other parts of the country where the arrangement and position of the rock strata are favorable, artesian wells (p. 209) supply large amounts of water.

Sand and gravel are in general good water bearers, while clay yields relatively little water (Why?). Many wells sunk in the glacial clays of northern United States obtain their water chiefly from beds or pockets of sand and gravel in the drift. Among the solid rocks, sandstone is a good water carrier, because it is porous, and shale a poor one, because it is compact. Granite and many similar rocks are dense, and hold little water, the largest supplies being found in cracks and other openings in the rocks.

(4) Thousands of lakes, particularly in the glaciated parts of the country, may serve as sources of water supply for neighboring cities and villages, and many are so used now. From the Great Lakes or their connecting rivers, Buffalo, Cleveland, Detroit, Milwaukee, Chicago, Duluth, and many smaller cities get their supply of water. (5) Many villages and cities get their water from streams. Thus New York City's supply is from streams and reservoirs in the Catskill Mountains and the uplands east of the lower Hudson River; Philadelphia depends on the Delaware and Schuylkill rivers, Cincinnati on the Ohio, Minneapolis and St. Louis on the Mississippi, and Omaha and Kansas City on the Missouri.

In recent years various cities have outgrown their supplies of water and have had to seek new supplies, in some cases at considerable distances and at great expense. Los Angeles is expending more than $25,000,000 in this way. Water is to be brought from Owens River, across the Mojave Desert and through the San Bernardino Mountains, in an aqueduct of steel and concrete some 240 miles long. New York City is expending nearly $100,000,000 to obtain an additional supply of 500,000,000 gallons a day from the Catskill Mountains, more than 80 miles away.

Quality of waters. Drinking water should be reasonably clear, tasteless, and free from germs of disease. Some cities have expended large sums to guard the purity of their water. Some of them have bought large tracts of land, with their lakes, springs, and other stream sources. The waters of these tracts are then protected carefully from contamination, and carried to the cities in ways that prevent pollution on the way. Other cities have established filtering plants through which all the city water passes before

use. Nevertheless, the use of impure drinking water is still a leading cause of disease in the United States. Many wells receive drainage from barnyards and cesspools (p. 207), many springs used as a source of drinking water are exposed to surface wash and to pollution by stock, and many villages and cities use river and lake water contaminated by sewage.

For many industrial purposes, the value of water depends on the kind and amount of mineral matter it contains. Distilleries and breweries require water of exceptional purity. Laundries and textile mills need water which is clear, free from iron, and contains little other mineral matter. Railroad companies spend large sums in treating the waters used in their engines, so as to make them less injurious to the boilers. Knowledge of the quality of the waters of the country is so important for various reasons that extensive investigations of surface and ground waters are being made by the United States Geological Survey, and by various state and private agencies.

Questions

1. Are cities more likely to develop on the *inside* or *outside* of great bends on navigable rivers? Give examples and reasons.

2. Why does the cost per ton for transportation by water tend to decrease as the size of the cargo increases?

3. Why are four-fifths of the population of New York state in the counties bordering the Hudson River and Erie Canal?

4. (1) Account for the enormous amount of water power available in the Northern Pacific district, according to the table on page 290. (2) Why do the western tributaries of the Mississippi River afford more power than the eastern tributaries? (3) Why does the Northern Atlantic district (p. 290) furnish more water power than the Southern Atlantic?

5. Explain the fact that apples and other fruits are grown in great perfection and abundance on irrigated lands around Grand Junction, in western Colorado, while in the same latitude in western Nevada attention is given largely to hardier crops, such as grain and potatoes.

6. Account for the fact that legislation concerning the utilization of stream and ground waters is more advanced in western than in eastern United States.

CHAPTER XVII

MOUNTAINS AND PLATEAUS AND THEIR RELATIONS TO LIFE

Mountains and plateaus have been referred to frequently in earlier pages. The more important points concerning their origin, their history, and their relations to human affairs are considered in this chapter.

Mountains

Distribution of mountains. As already noted, mountain ranges are situated in general toward the borders, rather than in the interiors, of the continents, and most of the longer and higher systems are not far from the edges of the greatest ocean basin. The settling of the ocean basins, due to the shrinking (partly through cooling) of the earth, may have been an important cause of the uplifts which have made mountains near the edges of the continents.

Leading types of mountains. (1) Fig. 208 shows several mountain ridges of one type, and suggests their origin. A plateau or plain was divided by giant cracks into a series of great blocks, which were displaced (*faulted*), the relatively elevated edges forming mountain ridges. The mountain ridges may be due to uplift, or to the sinking of the lower land adjacent to them, or to both. Such mountains are called *faulted* or *block mountains*. Block mountains in various stages of dissection occur in Oregon, Nevada, and elsewhere.

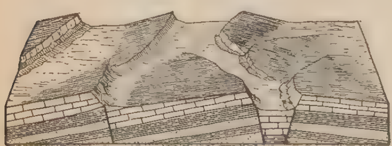


Fig. 208. Diagram of block mountains. (Modified after Davis.)

(2) Mountains consisting of a series of folds formed by compression from the sides are a common type. In some cases the folds are open and regular (Fig. 209); in others they are closed, irregular, and overturned. In some cases the strata of the folds are faulted

(Fig. 210), and some of the faults record a vertical displacement of thousands of feet. The present topography of most folded mountains—for example, of the Appalachians and Juras—is controlled not

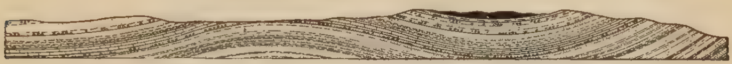


Fig. 209. Open, symmetrical folds in the Appalachian Mountains. Northeastern West Virginia. Length of section, about 12½ miles. The formation shown in solid black contains coal. (After U. S. Geol. Surv.)

so much by the original folding and faulting as by later erosion and warping.

(3) Many of the higher isolated mountains are *volcanic cones* (p. 193; Fig. 99). Many mountains have been formed also by great

Fig. 210. Folded and faulted strata in the Appalachian Mountains near Bristol, Virginia. (After U. S. Geol. Surv.)

intrusions of lava which have domed or lifted the overlying beds high above the level of the surrounding country (Fig. 105). In many such cases the rocks which covered the lava have been partly removed by erosion, exposing the core of intruded rocks (Fig. 211). Among the mountains produced chiefly by vulcanism and later erosion are the Henry Mountains of Utah, and the Park and Elk ranges (Fig. 212) of Colorado.

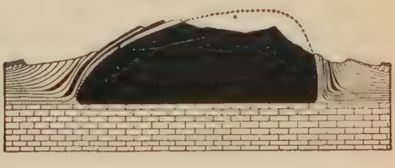


Fig. 211. An eroded laccolith. Cross-section of Mount Hillers, Utah, with ideal representation of the underground structure. Compare with Fig. 105. (After Gilbert, U. S. Geol. Surv.)

(4) Many mountains owe their existence simply to the resistance of their rocks, which have been left standing in bold relief by the removal of the surrounding weaker rocks. Many mountain peaks, aside from volcanic peaks, are of this origin. Pike's Peak, Colorado, is a

Fig. 212. Cross-section of Elk Mountains, Colorado.

well-known example. The Catskill Mountains of southeastern New York are due to unequal erosion, where the resistance of the rock is not very unequal. They are really a dissected plateau. Various other maturely dissected plateaus of considerable relief are called mountains.

(5) Folding and faulting, vulcanism and unequal erosion all may be involved in the formation of lofty mountains. Many mountains, furthermore, have had several periods of growth, between which the upraised beds suffered great erosion (Fig. 213).

The formation of mountains is a very slow process, probably occupying, for the greater ranges, hundreds of thousands or even

Fig. 213. Diagram showing structure of the beds in the region of the Santa Lucia Range, California. Length of section, about 11 miles. (After U. S. Geol. Surv.)

millions of years. Many mountains appear to be growing now — for example, the St. Elias Range of Alaska.

Destruction of mountains. All mountains are destroyed in time by erosion, unless renewed by vulcanism or uplift. Furthermore, the erosion of mountains commences as soon as they begin to rise, and continues throughout the long period of their growth, as well as afterwards. As a result, no mountain due to vulcanism or *diastrophism* (crustal movements) ever had the full height which those processes would have given it, if there had been no erosion. As already pointed out, many mountains have been nearly or wholly removed by erosion, and revived again by uplift, and some of them have passed through this history several times. The length of the life of a mountain which has ceased to grow is determined largely by its height, by the resistance of its rocks, and by the character of the climate.

The gentle slopes of the later life of a mountain are worn less rapidly than the steeper slopes of its earlier career, so that its old age may be longer than its youth and maturity combined. All lofty mountains are rather young, geologically speaking; old mountains have been worn low. While very old mountains are low, obviously not all low mountains are old.

Mountains as barriers. Mountains are barriers to the movement of animals and men, and to the spread of plants (Fig. 214). The effectiveness of a mountain barrier depends largely on its height, length, and width; on the number, height, and distribution of the

Fig. 214. Toltec Gorge, in the mountains of Colorado. Travel even along the valley is difficult. (Denver and Rio Grande Railroad Company.)

passes; and on the number of ridges, and the steepness and character of their slopes. The high, massive ranges of the Pyrenees, Caucasus, and Andes mountains form very effective barriers. The Pyrenees make the best natural inland boundary in Europe, shutting off Spain so completely from the rest of the continent that it has been said: "Africa begins at the Pyrenees." Although high, the Alps Moun-

tains have several good passes, well distributed; accordingly, they form a less serious barrier. The effect of many mountain barriers has been lessened by the building of wagon roads and railroads, the cutting of tunnels, etc. In other cases, mountains are crossed only by a few difficult trails, along which wares are taken on pack animals or by human carriers.

For a long time, northern and central Europe was excluded by mountains from the culture of the leading Mediterranean countries. China is largely shut off from the rest of Asia by mountains, a fact of much importance in connection with the isolated development and backward state of that country. The Appalachian barrier helped to confine the English colonies to the Atlantic seaboard for a century and a half. This favored the development of compact settlements, and permitted much more rapid progress along many lines than would have been

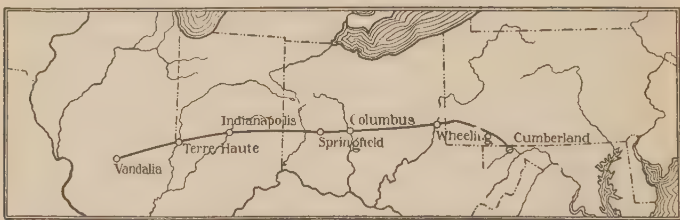


Fig. 215. Map showing course of Cumberland National Road.

possible had the colonists spread themselves thinly over a vast area, after the manner of the French, who controlled the St. Lawrence gateway into the Interior. For years after the Revolutionary War, the Appalachian Mountains made communication difficult between the settlements of the Interior and the seaboard. The first great step in their conquest as barriers to trade and travel was taken when the Cumberland National Road was completed from Cumberland, Maryland, to the Ohio River at Wheeling, in 1817 (Fig. 215); the second when the Erie Canal was opened (1825). Though this canal did not cross the Appalachians, it afforded an easy route to the Interior. The third and greatest step in the conquest of the mountains was taken when four railroads were finished across them in the 1850's. These first trans-Appalachian railroads crossed the barrier at the north, where it is narrowest, lowest, and has most good passes. Until the completion of the first transcontinental railroad (1869), travel across the western mountains and plateaus was so difficult that many people going to California chose the 13,000-mile voyage around Cape Horn, or the route by way of Panama.

The difficulty of crossing high, rugged mountains gives great importance to notches or passes in their ridges. Many mountain passes are water-gaps or wind-gaps; their formation has been explained, and their relation to human affairs illustrated (pp. 232, 234).

Trails, wagon roads, and railroads all seek the lowest and most accessible passes (Fig. 216). They commonly enter the mountains along main valleys, and, where necessary, zigzag up the steeper slopes to the passes which serve as gateways through the central ridges (Fig. 217). In some cases, railroad companies have avoided the last part of the ascent by tunneling the mountain below the pass.

Fig. 216. Sketch-map of region about Hollidaysburg, Pennsylvania, showing the influence of mountain passes upon the course of wagon roads and railroads. (From Hollidaysburg Sheet, U. S. Geol. Surv.)

South Pass, in central Wyoming, is the most important pass, historically, in the Rocky Mountains. Through it ran the famous Oregon Trail, along which many thousands journeyed to the grain lands of Oregon and the gold fields of California. Truckee Pass affords a relatively easy route across the central part of the Sierra Nevada Mountains. It was used first by the California Trail, and is used now by the Southern Pacific Railroad. The Pass of Belfort, between the Vosges and Jura mountains, connects the Rhone and Rhine valleys, and with them has constituted since ancient times one of the most important routes of travel between the Mediterranean and North seas. The passes in the mountains of northwestern India have served repeatedly as gateways through which tribes and armies from central Asia have descended to plunder and conquer the people of the plains.

The difficulties of travel and communication in rugged mountains shut their inhabitants away from the outer world, helping to retard progress. Old customs, fashions, and manners of speech are likely to be preserved by mountaineers long after they have been abandoned elsewhere. Education is backward; much of the simple clothing, furniture, etc., is home-made; trade in many cases is limited to barter, involving only the absolute essentials of life; and social intercourse is restricted seriously, favoring the close intermar-

riage of families and the development of "clans." These conditions are illustrated among the mountaineers of the southern Appalachians

Fig. 217. Road zigzagging up mountain slope in Switzerland. Rhone Glacier in middle background.

(Fig. 218). They do not exist, of course, in new mountain communities established by progressive people from outside, and they have

Fig. 218. Homes of mountaineers in the southern Appalachians.

been changed greatly in some long-settled mountains (e. g., in the Alps) by the coming of summer visitors (p. 317), and in other ways.

Many mountains are important climatic barriers (p. 77), and the conditions of life on their opposite sides may be very different. The western slopes of the Sierra Nevada Mountains receive much rain; to the eastward stretch broad deserts. Because most of its early mines proved disappointing, and lack of rain prevented ordinary farming in most places, the population of Nevada was always small (only 42,000 in 1900). This was the penalty of its position to the leeward of high, rain-catching mountains. Recently the population of Nevada has increased (p. 330) because of irrigation and the discovery of new mineral wealth. The contrast is even greater between the two sides of the Himalaya Mountains; to the south are the crowded millions of India, to the north the scattered, nomadic tribes of Tibet. The difference here is not due wholly to the mountains, but largely to the great altitude of the plateau on the northern side.

The settlement of mountains. In general, the settlement of rugged mountains begins only after the more inviting neighboring lowlands have been occupied, and their populations are always relatively sparse. The areas of the Adirondack, Catskill, Alleghany, and other mountains in eastern United States were blank spaces on the earlier census maps (Figs. 276 and 278), and their populations are in most sections sparse even now (Fig. 281). A similar situation exists in the western mountains.

Mountain areas are settled first and most thickly in their larger valleys. Here the flatter land favors tillage, soils are thicker and in most cases more fertile (Why?), the climate is milder, and the trails of the upland are replaced by roads.

The inhabitants of many mountain valleys in Europe and Asia are descendants of people who sought refuge there from their enemies. The Basques, who dwell in the western valleys of the Pyrenees, are an example. In other cases, the occupation of mountain strongholds has permitted people to dominate the adjoining lowlands, and levy tribute on their inhabitants. At the beginning of the Revolutionary War, four-fifths of the Cherokee Indians dwelt within the southern Appalachians, and from their mountain villages they repeatedly made sudden attacks on the frontier outposts of the whites.

Agriculture in mountains. Outside the valley bottoms, conditions are unfavorable to agriculture in high mountains, and in many places prevent it. Many slopes are too steep to be tilled, consisting either of bare rock or having here and there a thin covering of soil which washes easily when cultivated; and with increasing height, the climate prevents the raising of crops and even the growth of trees and grasses. Switzerland is largely mountainous, and only

about $^1/_6$ of its area is arable land. Only $^1/_7$ of the three Alpine provinces of Austria is tillable. Less than $^1/_6$ of Japan can be cultivated readily. Such conditions mean a scanty food supply and a constant tendency toward over-population. They mean also that in many long-settled mountain regions the cultivable land is farmed intensively

Fig. 219. Terraces made by Ifugao Igorots, island of Luzon, Philippine Islands.

in small holdings. Every effort is made to maintain the fertility of the soil, so that it may grow good crops continuously.

In many mountain regions, where all the level land has long been used, the slopes, too steep for agriculture by ordinary methods, have been utilized by making terraces (Fig. 219). Low walls are built one above another on the slopes, and the spaces behind filled in and covered with soil. In this way, successive tiers of nearly level benches of land (terraces) are made. Terrace agriculture is practiced in parts of India, China, Italy, Germany, France, Switzerland, and other countries. In Europe, much terraced land is used for vineyards. Choice

fields with bearing vines equal in price the best irrigated fruit lands of western United States (p. 175).

The crops which may be grown in mountains vary with the exposure, the altitude, the rainfall, the character of the soil, etc. In general, the slopes of a lofty mountain present successive climatic zones to which plant life, and animal and human life as well, are adjusted. If such a mountain is in low latitudes, its slopes may afford

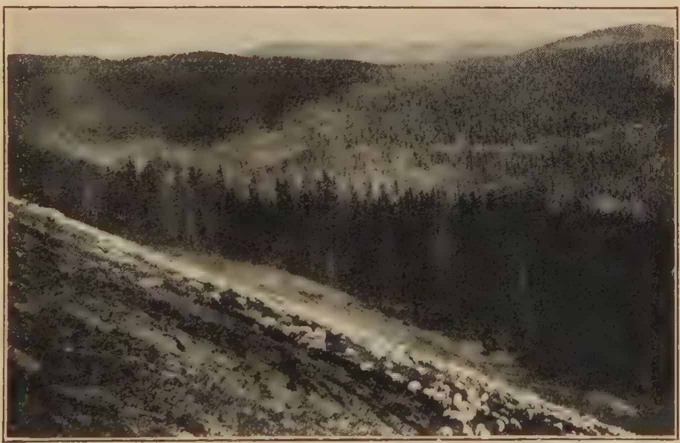


Fig. 220. Sheep grazing on a mountain side in Holy Cross National Forest, Colorado. (U. S. Forest Service.)

conditions ranging from those of the tropics to those of the polar zones (p. 22). In the Alps, the following changes may be noted: (1) In suitable places on the sides of the lower valleys there are vineyards, olive orchards, and mulberry groves worked intensively by a relatively dense population. (2) Higher up, these are replaced by grain fields and pasture lands, among which there are forests of deciduous trees. This zone is less productive and settled less thickly than the first. (3) Still higher, hardy evergreen trees prevail, the proportion of useless land increases, only the hardiest grains are grown (up to about 5,300 feet) in small fields by the sparse population, and most of the land with soil is devoted to pasturage and to the growing of hay for the winter feeding of the stock. (4) Above the "*tree-line*" (the upper limit of tree growth is about 7,600 feet) is a belt in which some of the slopes bear grass, where cows, sheep, and goats are pastured for a

short time in summer. (5) Finally, there is a waste of bare, rocky slopes and snow-fields, unoccupied by life which is useful to man.

Stock-raising in mountains. Stock-raising is an important industry in many mountains, for slopes too steep or too rocky to be tilled, or too high for cultivated crops to ripen, may afford pasturage (Fig. 220). As suggested above, pasturing stock and growing feed for its use in winter constitute a leading industry in the higher Alps. More than half the productive area of Switzerland consists of pasture

Fig. 221. Summer grazing in the High Alps.

land and hay land. In spring, herdsmen take their cattle, goats, and sheep from the villages in the valleys up to the high pastures, advancing, as the growth of the grass permits, close to the snow-line (Fig. 221), where the grazing season may last only six or seven weeks. In autumn, the flocks and herds are driven back by stages to the lower valleys, where they are fed in stables during the long winter. Raising enough hay and other fodder for the winter feeding is perhaps the most difficult part of the industry, and this requires hard labor during the summer. Stock-raising of one kind or another is a leading occupation in the mountains of Norway, Germany, central Asia, western South America, western United States, and elsewhere.

In western United States great numbers of cattle and sheep feed on the grass of the public domain (land owned by the government). The use of much of the public domain is free and unrestricted. While this has had its advantages, it

has resulted, at many times and places, in the overstocking of the range (pasture land), and a decrease in its capacity. Some system of regulation is likely to be adopted soon. Grazing in the National Forests is regulated now.

Mining in mountains. Many mountains contain valuable ore deposits, and mining is one of the most distinctive of mountain industries. The original source of most of the valuable metals appears to have been the *igneous rocks* (hardened lavas), and great intrusions of the latter form the central cores of many mountains. The metals probably were scattered widely through the igneous rocks to begin with, and were slowly concentrated into *ores* in veins, largely by

Fig. 222. Bisbee, Arizona, a city which grew up about copper mines.

ground-waters (p. 212). These veins are, for the most part, in or near the igneous rocks. Many of them have been exposed, and so made available to man, by erosion. The iron and copper of the Lake Superior region occur in the rocks of old, worn-down mountains. Much of the gold mined in the West has come from igneous rock, and from the immediate surroundings of great intrusions of lava. In northeastern Pennsylvania the folding of beds of rock containing layers of coal helped to change the latter into "hard coal" or *anthracite*. Much of the coal of this region was carried away later by erosion, but much was preserved in the down-folds of the mountains (Fig. 209). More than 80,000,000 tons of this coal are mined yearly (90,000,000 in 1911), and much of it is sent throughout eastern and central United States.

Cities have grown quickly from rude mining camps following the discovery of rich mineral deposits (Fig. 222). Thus in the late 1870's Leadville, Colorado, became a city of 15,000 people in a

few months, though in a sage-brush valley then difficult to reach, and at an elevation of 10,000 feet. Again, important mineral deposits may help to gather a dense urban and industrial population about the borders of the mountains in which they occur, as in the case of the Pennine Mountains of north-central England, and the Erz (meaning *ore*) and Riesen ranges of Germany, where mining has been carried on for many years.

Mountains as forest reserves. The slopes of many mountains have been left largely in timber because unsuited to agriculture, and various mountain ranges now support important lumber

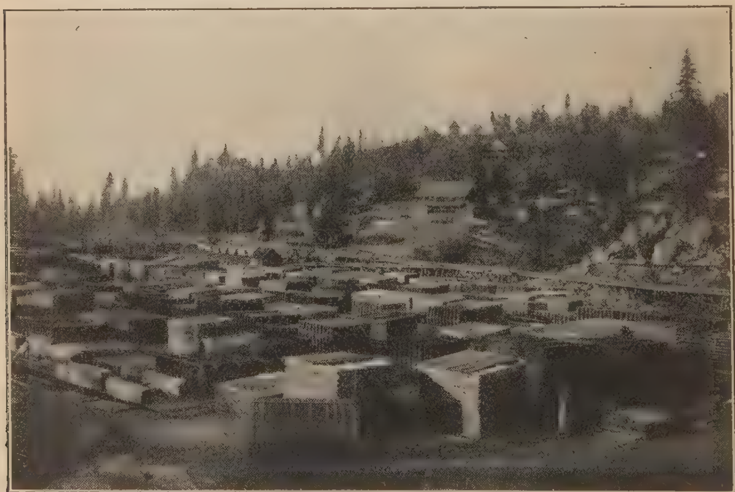


Fig. 223. Modern lumber mill in the Sierra Nevada Mountains, California. (U. S. Forest Service.)

industries (Fig. 223). The relation of mountain forests to the flow of streams rising in them, and to the problems of navigation, water power, irrigation, and soil erosion has been noted (pp. 169, 290, 298). These problems, together with the need of insuring a permanent lumber supply, have led various countries to regulate the use and cutting of mountain forests, and to provide that certain areas remain forest-covered.

Japan has many steep volcanic mountains, whose slopes, if uncovered, would be eroded rapidly by the heavy rains; this helps to explain the fact that nearly 3/5 of the country has been left in forest reserves, although the nation is in great need of more farm land. Among European countries, Germany, Switzerland, and

France have skillfully managed forest reserves on mountain slopes. Some of the Mediterranean countries show the evils which may follow the cutting away of mountain forests. In Dalmatia, for example, mountain slopes once forested consist now of bare rock, and are of little use to man. In parts of eastern and northeastern China the forests are gone, and one may travel hundreds of miles without seeing a single grove on the hill sides. Even the undergrowth has been destroyed, and in places all grass and other vegetation suited to the purpose are gathered for the cattle, or eaten by goats and sheep.

Serious results have followed: (1) Heavy rains cause violent floods. Valleys usually without streams may be occupied suddenly by torrents which destroy bridges and buildings, ruin fields, and then disappear within a few hours. (2) In many places not enough water enters the ground to keep the water table sufficiently near the surface for the good of plants. (3) Erosion has been increased enormously (Fig. 80). Large lowland areas are covered with coarse waste, and much fine material is swept into the sea. (4) Timber is at a premium. In the western mountains forest destruction is less advanced, and travelers report meeting long lines of coolies carrying boards down to the plains, where they are worth the equivalent of $2 to $3 each, a value which restricts their use to special purposes, such as making coffins.

Most of the National Forests of the United States (p. 298) are in the mountainous districts of the West (Fig. 207), where the greater part of the timber is found on the mountain slopes because the latter receive more rain than the surrounding plateaus and plains. Congress provided in 1911 for a National Forest in the southern Appalachians, where the maintenance of a forest cover on many of the slopes is of great importance (pp. 173, 221).

Mountains as pleasure resorts. The cool, invigorating summer climate and beautiful scenery of many mountains lead thousands of lowland dwellers to visit them yearly. The mountains of New England, the Adirondacks, Catskills, and parts of the Alleghanies, contain many popular resorts. With the growth of population in western United States, the mountains of that section probably will be visited more and more.

Most of the National Parks (Fig. 224) and National Monuments are in the West, and a number of them contain mountains or portions of mountains of unusual beauty and interest. The National Parks, of which there are 13 in continental United States, were created by Congress, and serve various purposes; they are intended especially to be "play-grounds for the American people." In 1905 the President was given power to set aside from the public domain as National Monuments any "historic landmarks, historic or prehistoric structures, or other objects of historic or scientific interest." There are now twenty-eight National Monuments, of which the Mount Olympus, Washington, and Grand Canyon, Arizona, monuments are largest.

The Alps, situated in the midst of densely settled countries, are the most beautiful mountains in Europe, and have come to be perhaps the greatest summer resort in the world. Hundreds

of hotels (Fig. 225) depend upon the tourist trade, and the entertainment of visitors has become almost a national industry.

Other mountain resources and industries. Fur-bearing animals constitute an important resource of some mountain regions. They were once a resource in many others where few are left.

From about 1807 to the middle of the century, the fur trade in the Rocky Mountains of the United States was of great value. Trading posts were established in the mountains and along the larger rivers flowing eastward from them,

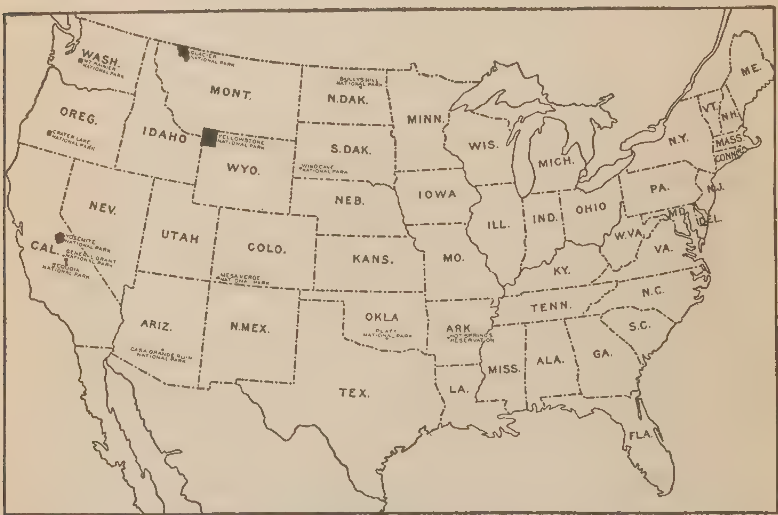


Fig. 224. Map showing distribution of National Parks.

at which a driving business was done. St. Louis was the great depot and outfitting point of the trade. The trappers and traders were the pathfinders of the West. The fur trade is still of some importance in the mountains of western Canada.

We have seen that many mountain people are forced to make most of their own clothing, implements, utensils, etc. (p. 309). In addition, many of them make special articles of superior quality for sale. In this way they eke out a living, and find work during the winter months when little can be done out of doors. From wood, metals, wool, or other raw material at hand, they make artistic wares which are suited to mountain transportation, and command ready sale. Such are the carved wooden wares of the Swiss, and the lace made by some of the Italian mountaineers.

Many mountain streams afford much water power (pp. 248, 256, 290) which will be used increasingly in the future. In most cases, however, much of the energy will be carried outside the mountains in the form of electricity, to be used in the lowlands.

Plateaus

Distribution. As stated elsewhere (p. 21), large plateaus occur for the most part in three classes of situations. (1) Some of them are between a lower plain on one side and higher mountains on the other,

Fig. 225. A summer hotel in the High Alps.

(2) some are between mountain ranges, and (3) some rise abruptly from the sea, or from narrow coastal plains.

Origin. Plateaus are formed in various ways. (1) Some have been built by many lava flows, like the Columbian Plateau of the Northwest (Fig. 104) and the Deccan Plateau of India. (2) Adjacent land may have been worn low or warped down, leaving a plateau. (3) The plateau may have been warped or faulted above its surroundings.

The erosion of plateaus. Like mountains, all plateaus will be worn down to lowlands, if not made high again. Mature plateaus are table-lands well dissected by streams; the surface is carved into hills (or mountains) and valleys (or canyons), and slope and relief are at a maximum. Some dissected plateaus are called mountains (e. g. the Catskills, p. 306). In one sense there are no old plateaus, for, when worn low, they are plains.

Conditions of life on plateaus. The conditions of life on high, dissected plateaus are much like those in mountains situated similarly (pp. 309–318), while the conditions on many low plateaus resemble closely those on neighboring plains (Chapter XVIII). Large plateaus in continental interiors surrounded by mountains are, in general, deserts, and subject to great ranges in temperature. Accordingly, they are settled sparsely. Farming is confined for the most part to the slopes of waste at the bases of rain-catching mountains, where water may be led from the withering streams for use in irrigation. The greater part of such plateaus is uninhabited, save by bands of wandering nomads, as in central Asia, or by occasional ranchmen whose cattle and sheep graze on the thin and scattered growth of grass, as in parts of western United States.

The habitability of a high plateau is influenced greatly by its latitude; while such a plateau is cold and uninviting in the temperate zone, it has a temperate climate in the tropics, where, if other conditions are favorable, it may have a population much denser than that of the neighboring lowlands.

Nearly three-fourths of the people of Bolivia live at altitudes of 6,000 to 14,000 feet, and of the nine most thickly settled provinces, five are at elevations greater than 11,000 feet. Three-fourths of the population of Ecuador are found in the plateau basins of the Andean highlands, at an average elevation of 8,000 feet. There is a striking contrast also between parts of the cool plateau and the hot lowlands of Mexico. The former have relatively dense and progressive populations, while the latter are settled sparsely by backward Indians. In higher latitudes, plateaus for various reasons are in general settled much less densely than the neighboring plains, as already indicated. The Great Basin and Columbian Plateau of western United States each contained, in 1900, only 0.5 per cent of the population of the country. In these regions the population numbered only 1.6 and 3.2 persons, respectively, per square mile. The sparsest population of Great Britain is found in the Highlands of Scotland.

Fig. 226. Sketch of mountainous region.

Questions

1. (1) In what stage of erosion are the mountains shown in Fig. 226? (2) How will the slopes of these mountains be changed in the future?

2. (1) What is the age, in terms of erosion, of the mountains shown in Fig. 208? (2) What was the topographic age of the surface from which the mountains were formed? The evidence?

3. (1) Compare and contrast the climate of the mountains and plain shown in Fig. 227. Why the differences? (2) What work are the streams doing in the mountains? On the plain? Reasons in each case? (3) What kinds of soil would you expect to find on the plain just west of the mountains? Why? (4) What

Fig. 227. Portion of Paradise, Nevada, topographic sheet. Scale 4 miles per inch. (U. S. Geol. Surv.)

does the map suggest concerning the chances for successful agriculture in the different parts of the area?

4. Compare and contrast the relations of mountains to the life of (1) primitive and (2) advanced peoples.

5. Account for the fact that houses in arid plateaus often are built with flat roofs and thick walls.

CHAPTER XVIII

PLAINS AND THEIR RELATIONS TO LIFE

Origin and classes of plains. Various types of plains have been discussed in previous pages, and some of their relations to human affairs noted. Rivers make *flood-plains* (p. 236), *delta plains* (p. 241), and *peneplains* (p. 227). The ancient ice-sheets formed vast *drift plains* or *glacial plains* (p. 260). The floors of extinct lakes form many nearly flat *lake plains*, especially in glaciated regions (p. 262). Most lake plains are small.

Extensive plains, like the Atlantic and Gulf coastal plains of the United States and the vast interior plain which stretches from the Appalachians to the Rockies, cannot in most cases be put in any of the above classes. They commonly contain many smaller plains of several or all of the types mentioned. In general, large coastal plains were once marginal sea-bottoms, and were made into land by being raised or by the sinking of the sea. Coastal plains may also be peneplains, or they may be land made by the filling of a shallow sea border by sediment washed from the land. Large interior plains are either areas worn low, or, in more cases, they are former coastal plains now separated from the sea by newer land. The changes made in plains by erosion were discussed in Chapter XV.

Distribution of extensive plains. Most of the great plains of the world are in the northern hemisphere. The northern parts of the large plains which border the Arctic Ocean are of little value to man, but there are vast, fertile plains in the north temperate zone which are of great importance in the life of the world. The southern continents are unfortunate in having their largest lowlands within the tropics, where climatic conditions retard human progress.

General advantages of plains. From the standpoint of human occupation, plains which possess a favorable climate have distinct advantages over mountains and plateaus. In general, the slopes of plains are gentler, their soils thicker and more fertile, and they have a much smaller percentage of useless land. Their advantages

of climate, soil, and topography make plains the great agricultural regions of the world. In this connection it should be remembered that agriculture is the basis of all lasting advance in civilization. Movement is relatively easy on plains, and difficult in mountains (p. 307). This means that goods and ideas circulate more readily, and that trade and culture develop more rapidly, among lowland people. In mountains, a great variety of conditions may be found within a small area, while on plains, similar conditions may prevail over large areas. It follows that most occupations of plains have a much wider distribution than those of mountains.

Because of the advantages of lowlands for agriculture and trade, the great majority of the people of the world live on them. The relatively dense populations of the favored lowlands of the United States are shown by Fig. 281. More than 9/10 of the people of the country live on lands less than 1,500 feet above the sea. While this shows that most of the people live on plains, it will be remembered that there are plateaus and mountains lower than 1,500 feet, while a part of the Great Plains is much higher. Less than 1 per cent of the people live at elevations of more than 6,000 feet.

Contrasts among plains. Apart from their mode of origin, plains differ in many ways. They may be large or small, high or low, rough or smooth, forested or treeless, fertile or infertile, wet or dry, and they may be in hot, temperate, or cold regions. Furthermore, there are all gradations between these extremes. These differences affect human interests in important ways, many of which have been noted.

Relatively small plains protected by natural barriers, rather than large, open ones, favor early progress in civilization. A small area hastens advance to the agricultural stage (Why?), and as the population increases, laws and customs are made in the attempt to overcome the friction which goes with crowding. The isolated and protected plains of Greece possessed many advantages for early progress. On the other hand, all parts of a vast plain not protected by barriers, such as that of Russia, are open to attack. It is easy for the people of a large plain to scatter in search of game and other food, and the natural food supply may be sufficient to postpone indefinitely the development of agriculture. Extensive plains, such as those of central United States, afford excellent conditions for the further progress of a people already advanced in civilization. This is especially true where, as in the case cited, such plains have varied geographic conditions and resources in their different parts.

Climate is the most important factor affecting the life of extensive plains, and the larger plains of the world are so distributed with reference to climate that the conditions of life in them may

be discussed briefly under the following headings: (1) Life in well-watered plains of middle latitudes. (2) Life in semi-arid plains. (3) Life in desert plains. (4) Life in Arctic plains. (5) Life in humid plains of low latitudes. The more important direct effects of various types of climate on life were discussed in Chapters IX, X, and XI.

Life in Well-Watered Plains of Middle Latitudes

Plains in middle latitudes having plenty of rain are the seats of advanced civilizations, and some of them support dense populations. The soil is the most important resource of these plains, and agriculture the most wide-spread occupation. On the whole, they have less in the way of forests, minerals, and water power, than many highlands have, but plains are by no means without these resources. Lumbering and mining are carried on at many points, and commerce and manufacturing are developed highly in the thickly settled sections. In the complex life of these regions, the influence of geographic conditions is less apparent and less direct, but not less important, than in the simpler life of the grasslands and deserts.

Differences in soil, in the form of the land, in drainage, etc., have their effect on the distribution and occupations of the people. The influence of variations in soil is especially great, and may be seen in many places. In the glaciated plains of northern United States, various kinds of soil may occur within the limits of a good-sized farm. Here the intelligent farmer is likely to devote each type of soil to the particular use or uses to which it is adapted. In other places, the character of the drift over several or many square miles is determined by the nature of the underlying rock, so that, for example, an area of sandy drift, over sandstone, may lie beside an area of limey-clay drift, over limestone. In a certain region in south central Wisconsin, the condition of the people in two such areas is very different. The area of fertile, limey-clay soil is said to have been settled by people of greater means, while the sandy area was occupied by poorer people not in a position to choose. The original difference appears to have increased. In the one case, there are attractive homes with modern conveniences, large barns, many windmills, improved roads, and many well-equipped schools; in the other, many of the buildings are old and unpainted, few farms have windmills, roads are poor, and some of the schools are in an unsatisfactory condition.

The influence of soil on the distribution and activities of people may be seen on a larger scale in various parts of the Atlantic and Gulf coastal plains. In Alabama, the northern part of the state is underlain by old rocks (Fig. 228). This part was land when the area of the coastal plain was under water. Sediment washed from the old land helped to make the strata of the coastal plain. East and west across the middle of the state there is a low, nearly level belt of rich soil, weathered from the limestone beneath. This is the inner part of the coastal plain.

From its southern edge the ground rises rather abruptly some 200 feet, because of the outcrop of more resistant beds, and then slopes gently southward to the coast. The soils of this outer belt are much poorer than those of the inner lowland, except along the bottoms of the larger valleys, where there are deep, fertile loams. The history and present life of the state cannot be understood apart from these soil belts. The first American settlers, typical log-cabin pioneers, settled for the most

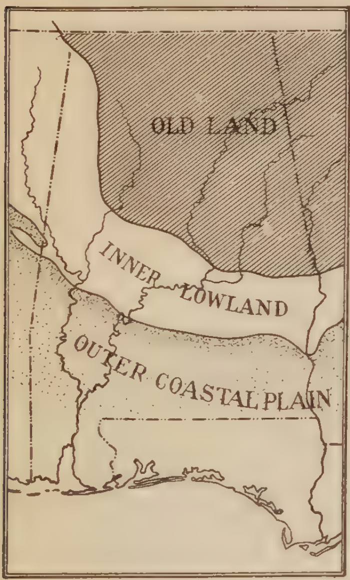


Fig. 228.

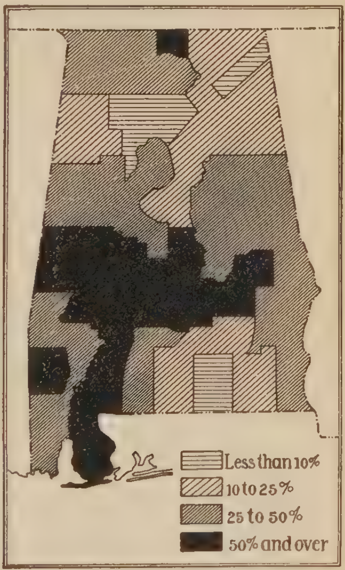


Fig. 229.

Fig. 228. Map showing principal physiographic provinces of Alabama.

Fig. 229. Map showing distribution of slaves by counties in Alabama (1860). Figures in legend indicate percentages of the total population.

part in the rich inner lowland and along the fertile valley bottoms. Later, this was seen to be the section best suited to the growth of cotton, and many of the earlier settlers were pushed by the slave-owning planters north into the foothills of the mountains, or south into the sandy areas of the outer coastal plain. The inner lowland contained the largest number of slaves at the time of the Civil War (Fig. 229), and more than $^3/_5$ of its present population are negroes. The outer zone of the coastal plain always has had a relatively sparse population, except along the larger valleys. There are still extensive pine forests where lumbering, the making of turpentine, and grazing are leading industries. Mobile is the only important city in this part of the state. It has a harbor at the drowned mouths of the leading rivers of the region, and is the natural gateway into the state from the south.

Life in Semi-Arid Plains

Large semi-arid plains occur in the belt of the trade-winds, where some of them merge into deserts, as in northern Africa and Australia. Others lie in the interiors of continents, where the prevailing winds which reach them have been robbed of most of their moisture in passing over mountains. The steppes of western Asia and the Great Plains of the United States are examples. The scanty rainfall of such plains or its unfavorable distribution prevents the growth of most

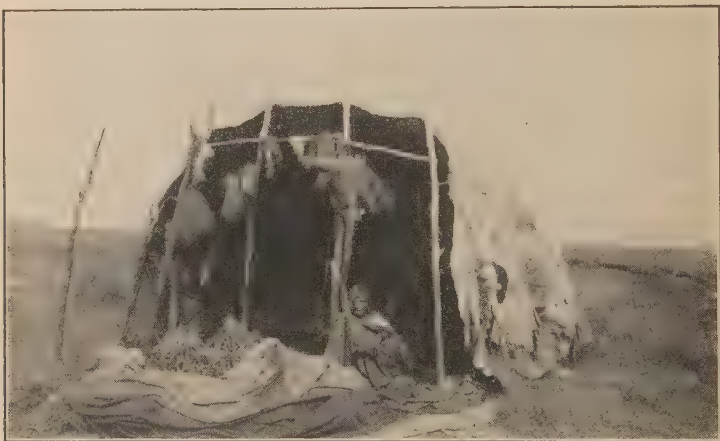


Fig. 230. Home of native nomad of Argentine Patagonia. (Harriet Chalmers Adams.)

trees except along the streams, and restricts useful vegetation to quick-growing grasses and a few other hardy types of plants.

Hunting tribes and pastoral nomads. Under primitive conditions, the inhabitants of semi-arid plains get their support from flocks and herds, or depend on the chase, like the buffalo-hunting tribes of earlier years on the Great Plains (p. 328). Both the pursuit of game, and the frequent need for fresh pastures with new supplies of water, cause the people to lead a nomadic life. The dwellings must be such that they can be moved easily (Fig. 230); in many cases they are tents of skins, or of felt made from wool. Personal effects and household utensils are few and light; and the most desirable form of wealth is flocks or herds, which transport themselves.

The movements of many pastoral tribes are regulated by the seasons. In some cases, their flocks and herds are driven in summer into the highlands, thus escaping from the hotter plains and using more of the pasturage. The Kirghiz of Russian Turkestan regularly take their flocks in summer up into the Altai Mountains, and bring them back to the lower lands in winter. Again, the more abundant grass and water of the rainy season may permit the people to gather in considerable groups in desirable localities, while in the dry season they are forced to scatter widely, to secure food for their animals.

The pastoral nomads of semi-arid plains always have been marauders and conquerors, though less so than the men of the desert (p. 333). Under favorable conditions, their growing herds and flocks require more and more pasture, and from time to time compel them to move beyond the boundaries within which they formerly had roamed. On the other hand a long and severe drought, resulting in less pasturage and a failing water supply, or disease among their animals, may bring them to the verge of famine, and drive them to pillage and conquest. Mounted on horses or camels, the nomads are able to make swift attacks on the people of neighboring lands, and to retreat quickly with their booty. For centuries, portions of agricultural Russia were pillaged repeatedly by hordes of horsemen from the southeastern steppes, and the Great Wall of China was built as a protection against pastoral nomads.

In general, it may be said that the conditions of life in semi-arid, grassy plains rarely, if ever, permit their native tribes to develop more than a low form of civilization.

Use of semi-arid plains by civilized people. Even where civilization is advanced, plains that are too dry for agriculture by ordinary methods are devoted largely to the grazing industry. Vast semi-arid areas are used in this way in the United States, Argentina, Australia, and Russia. By means of irrigation and special methods of cultivation, agriculture doubtless will be extended greatly in semi-arid regions in years to come.

The Great Plains. The history of the western portion of the Great Plains illustrates many of the conditions of life in semi-arid regions. Until after the Civil War, these plains were occupied by Indians dependent for a living on the great herds of buffaloes. The killing of the buffalo and the confining of the Indians to certain areas (reservations) opened the plains to the cattle industry. In the drier parts most attempts to farm by ordinary methods have been un-

successful, though here and there streams and wells furnish water for irrigation (p. 329). Within the last few years, "dry farming" (p. 329) has replaced the grazing industry in some places.

As already indicated, the buffalo was the most important factor in the lives of many Indians of the Great Plains. The chase required many quick moves, and this helped to keep families rather small, the houses light and portable, and personal property small in amount. Individual ownership of land was unknown among some of the tribes. The mythology of the Indians was tinged by their hunting and military habits. The chiefs attained their positions because of their skill as hunters or warriors. With the disappearance of the buffaloes, the hunting tribes lost their chief support, and became dependent on the white man. Great numbers of buffaloes were killed as food for the construction gangs of western railroads, and for their hides, which were in great demand in the East for robes, belting for machinery, and other purposes. They practically disappeared from the southern plains in the middle seventies, and from the northern plains a few years later.

The stock-raising industry of the Great Plains began in Texas and spread northward. Cattle were introduced into Mexico by the Spaniards about 1525, and before the Revolutionary War there were large cattle ranches north of the Rio Grande. In the middle 1850's, most of Texas was "a vast, unfenced feeding ground for cattle, horses, and sheep." At the close of the Civil War, cattle were very cheap in Texas, but brought high prices and were in great demand in the northern cities. As a result, the practice was developed of driving cattle northward in great herds to shipping points on the railroads that were then building across the Great Plains in Kansas and Nebraska. The "cow towns," as the shipping points were called, were established beyond the farming frontier, preferably where there was a good supply of water and grass. The business shifted west and south with the advancing railroads, keeping in front of the farming zone. The banner year of the Texas cattle drive was 1884, when 1,090,000 cattle were driven out of the state. Soon after, the drives were rendered unnecessary by the extension of railroads, which took the stock to market in much less time and usually in better condition. The stocking of the northern lands occurred, for the most part, after 1870, and before the close of another decade the business had spread to the Canadian boundary. For a time, large returns were realized from feeding cattle on the public grass. Many people accordingly went into the business, and in numerous places the range (unfenced pasture land) was overstocked and the pasturage injured. One result of this in many places was the introduction of sheep, which can live on pasturage that will not support cattle. The conflicting interests of cattlemen and sheepmen have caused much trouble in some of the grazing states. The development of the grazing industry on the Great Plains had an important influence upon the growth of the slaughtering and meat-packing industry in Kansas City, Omaha, St. Louis, Chicago, and (later) South Omaha, from which meat products were sent to the urban and industrial centers of the northeastern states and Europe.

In 1880, the Great Plains west of the 98th or 99th meridian were occupied only by stockmen, except along some of the larger valleys (Fig. 231). A few years later thousands of farmers moved there and began to grow wheat, using the seed and methods which they had employed farther east, where the rainfall is greater. The population of Kansas increased 250,000 between 1885 and 1888, largely in the

western portion (Fig. 232). The agricultural invasion began because of heavy rains in the middle eighties, and was kept up for a few years by the advertising of railroads and the activity of town-builders and land-dealers. Then came several very dry years, and thousands were starved out of the region. Kansas lost some 200,000 people, and the western parts of Nebraska, the Dakotas, and the eastern part of Colorado were affected similarly (Fig. 233). Millions of acres returned slowly to grass, and within a few years hundreds of "cities" were abandoned by their founders. Within the last few years, another agricultural invasion of the High Plains has been in progress. A series of wet seasons, the activity of land companies, and the introduction of agricultural methods adapted to semi-arid conditions have been the leading causes. The outcome is still uncertain, but is not likely to be so disastrous as the first settlement, because men know better now how to make use of dry lands.

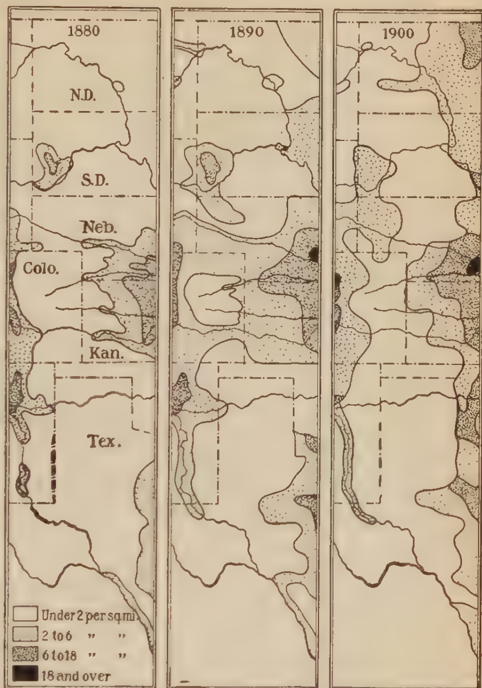


Fig. 231. Fig. 232. Fig. 233.

Figs. 231, 232, 233. Maps showing distribution of population on the western Great Plains in 1880, 1890, and 1900.

The chief uses to which the semi-arid parts of the Great Plains will probably be put in the future may be suggested briefly. (1) Farming by irrigation will be extended somewhat, but the amount of water available from all sources is but a small fraction of what would be needed to irrigate all the land. (2) Dry-farming, especially with hardy, drought-resisting plants (p. 173), promises much more than irrigation for the region as a whole. Dry-farming scarcely can be said to have passed the experimental stage, and how large an area can be dry-farmed successfully is quite uncertain. As already pointed out (p. 65), dry-farming seeks (a) to get the largest possible amount of the rainfall to enter the ground, and (b) to reduce to a minimum the loss of water by evaporation from the soil. (3) Stock-raising, and stock-raising with subordinate farming, apparently must remain the leading industries over large areas.

Life in Arid Plains

About $^1/_5$ of the land is desert for lack of rain. By no means all dry deserts are plains; some are plateaus, and within desert plains and desert plateaus there may be ranges of high hills and mountains (p. 334), though these, in most cases, receive more rain than their surroundings. Many of the conditions of life are similar in arid plains and plateaus, and they are considered together. Life in *cold deserts*, such as parts of the Arctic plains (p. 336), differs greatly from that in dry deserts. Only the latter are considered here.

The great deserts of the world are in the zones of the trade-winds, or to leeward of high mountains. Their wide distribution and vast extent, the location of some of them near well-watered and thickly-settled regions, and the relations of their people to their neighbors, always have given deserts great importance in the life of the world. Except in the relatively small areas where irrigation is possible, or to which people may be attracted by valuable mineral deposits, deserts are doomed to have scanty populations.

The power of mineral deposits to bring people to deserts is illustrated strikingly in Nevada. The deposits of gold and silver first discovered there attracted thousands of miners and prospectors, and made Nevada a state in five years. Later, the population of the state declined greatly (p. 311), but in the last decade it has increased again (81,000 in 1910) due to new discoveries of ore. Butte, Montana, a city of 39,000 inhabitants, is supported largely by deposits of copper that underlie less than two square miles of arid land which, without the mines, could support only a few people.

Plant life in deserts. Plants require water for growth, and they lose water chiefly by evaporation from their leaves. It is clear that plants with unusual ability to get and store water, and plants which lose but little water, are best suited to deserts. Most desert plants are provided with many long roots, which enable them to get more moisture from the dry soil than would be possible otherwise, and at the same time help them to stand against the winds, often of great strength. The loss of water from the plant is reduced by such things as thick skins, corky bark, and coats of hair. Some desert plants have no leaves, and some have only a few small, rounded, and fleshy leaves. Thus the loss of water by evaporation is diminished. Many desert plants have thorns, spines, and unpleasant or poisonous juices, which help to protect them against devouring animals. Scattered shrubs and coarse grasses are among the leading types of desert

vegetation. Fig. 234 shows desert plants of various kinds. The plants of deserts have little economic value at the present time. The vegetation of oases (p. 334) is quite unlike that of the desert.

After rain falls in the desert, many small, quick-growing plants spring up, some of which bear bright flowers; but soon they wither and die for lack of sufficient water.

Animal life in deserts. Like certain plants, some animals have developed characteristics which help them to live in the desert. The severity of desert conditions is shown, however, by the small

Fig. 234. View in the desert near Tucson, Arizona. (W. L. Tower.)

number and the small variety of animals which can endure them. Like desert plants, desert animals are, as a rule, scattered. Some are very fleet of foot, and thus are able to move between widely separated watering places and to escape from their enemies. Some are slow-moving, but most of these are venomous, and all of them are able to go without water for long periods. A desert is an impassable barrier to slow-moving animals which need water frequently. On account of the hot days and cool nights, many desert animals are more active during the night than during the day. Many of them are dull of color, and not easily seen against the barren ground.

The camel is the most important animal of the arid regions of the Old World, having long been called "the ship of the desert." It is found in northern Africa and in Asia (Fig. 235), from Arabia to China, and northward to northern Mongolia. A draft camel carries 300 to 600 pounds, according to size, the customary load being about 1/3 the weight of the animal. It is said that caravans sometimes travel 20 out of the 24 hours at a steady gait of 2½ to 3 miles an hour, halting only during the hottest part of the day.

The camel is well suited to desert conditions. It can travel far with a small supply of food and water; it has small nostrils, which can be closed so as to prevent the entrance of the finest wind-driven sand; eyes protected against sand and sun by long, heavy lashes; and peculiar padded feet, fitted for the hot sands. The parts of the body exposed most to heat and friction are protected by great callosities. When at rest in an oasis, a camel drinks only enough for the time being, but when on the march it makes provision for many hours in advance. During weeks of rest or light work, the hump increases in size; on long journeys, the material of the hump is absorbed into the system, keeping up the strength of the animal.

Human responses to desert conditions. Agriculture is impossible in deserts, without irrigation, and few places have enough water for that. Furthermore, grazing in many cases is possible only

Fig. 235. Camels in northwestern India. A portion of a caravan which has come through Khyber Pass from Afganistan.

along the margins of the desert, or in oases. Since deserts afford little food, they can support few people, scattered widely in small groups. The conditions in deserts permit native tribes to make little progress in civilization.

Along the borders of many deserts the conditions of life are a continuation of those in semi-arid grasslands (p. 326). The people wander from place to place with their flocks and herds, the size of the social group being determined by the supply of water and grass. Along the margins of certain deserts, the people sometimes do a little farming when the water supply permits, to add to the often uncertain and always restricted living afforded by their animals.

We have seen (p. 331) that deserts may support considerable vegetation for a short time after rain falls. Along the edges of certain deserts, pasturage is available in the wet season, even where the surface is bare in the dry season. This may

control the seasonal migrations of pastoral tribes. In winter, the Arabs find scant pasturage for their goats and sheep on the northern border of the Sahara; in summer, they drive them to the slopes of the Atlas Mountains. In the same way flocks and herds are driven at various points into the southern edge of the Sahara in summer, which is there the rainy season.

The arts of desert people are primitive and confined largely to household industries. Making leather and leather utensils from the skins of animals, pottery from clay, and blankets and rugs from wool furnished by the flocks, are typical industries.

Among American Indians, the potter's art was developed best in the arid Southwest. Here water was scarce, and durable, water-tight vessels were an absolute necessity. The Navajo Indians of this region possess large flocks of sheep, and sell wool and blankets. The latter are made by the women in many artistic designs, and enjoy a wide reputation.

From force of necessity, most wandering desert tribes are robbers. They pillage caravans and hold travelers for ransom, or exact heavy tolls in return for safe passage through the desert. They raid adjacent agricultural lands, and in some cases have levied regular tribute upon them, or have conquered and settled in them. The Sudan and Egypt have been invaded repeatedly by tribes from the Sahara.

The people of deserts are excluded more or less completely from the culture of the outside world. Hence, as in mountains (p. 309), old manners and customs persist. Customs of the time of Christ still are observed in the desert of Arabia. Scattered widely in small groups, desert people develop many dialects. They are compelled to eat very sparingly of the few things available. Nothing is wasted; the Tibbus of the Sahara eat even the skins and powdered bones of their dead animals. The scanty diet and severe hardships incident to life in the desert help to produce a distinct physical type. The men are commonly thin, but wiry, and capable of great exertion. Desert nomads have great powers of observation and a remarkable sense of locality. Intellectual activity necessarily is restricted in the desert. The dull scenery and the lonely life tend to lead the mind into reverie and contemplation. The majesty of the larger deserts, their vast extent, their great dust and sand storms, and the uncertain position of man, all tend to inspire feelings of awe and reverence. It is significant that Christianity and Mohammedanism were associated closely in their origin and development with the arid and semi-arid regions of the Old World.

Life in oases. In deserts, permanent settlements based on agriculture are possible only in oases, where there is water supplied by springs, artesian wells, or rivers. The source of the water supply may be outside the desert in well-watered regions, or within the desert where elevations rise high enough to compel the passing winds to give up a part of their moisture.

The Nejd Plateau, in the heart of Arabia, rises to an elevation of more than 5,000 feet, and here there are fertile oases, cultivated for centuries, and extensive pastures. Even in the Sahara, there are a few mountains which receive enough rain to support trees. The streams formed on these mountain slopes disappear after descending to the desert. Some of the narrow valleys are farmed, and grazing is possible over larger areas.

Some oases serve merely as headquarters for tribes which roam over the surrounding desert in search of pasturage, and of caravans which they may attack. Some support towns, most of which are small. In general, the larger towns are located on the main caravan routes, where there is better opportunity for trade (p. 335). The houses in many cases are built of stone or *adobe* (sun-dried clay). In many cases, oases are cultivated most carefully in order to secure the largest possible returns from the restricted area which can be watered. Vegetables, cereals, and fruits, especially dates, are grown in the oases of the Sahara and the deserts of southwestern Asia.

The date palm has a trunk in some cases fifty to sixty feet high, ending in a great crown of feathery leaves (Fig. 236). Bearing trees average from 100 to 200 pounds of dates a year, though yields of 500 or 600 pounds have been known. A tree may bear fruit for a century. The date palm is adjusted perfectly to conditions in the oases of low-latitude deserts, for it requires a dry, hot climate, and a moist soil. It has been said with truth that the Arabs built their lives on the date palm. In the future, the date palm probably will have commercial value in irrigated lands along the lower Colorado River (p. 242) and about Phoenix, Arizona.

Oases in deserts are in striking contrast with the barren land about them, though most of them are not such delightful gardens as they have been described. They are subject to frequent sand-storms, their water supply is small and in many cases impure, and their products are restricted in variety and in quantity.

Commerce of the desert. Where a desert lies between well-watered and populous regions, important trade may be carried on across it. Some trade is carried on also between agricultural lands and the borders of neighboring deserts, because of their contrasted resources and the desire of the desert people to supplement their

meager products. Timbuctoo, on the Niger River, and Damascus, in Syria, are examples of places which serve as gateways to deserts.

For centuries, goods were carried in large quantities across the vast deserts of central and western Asia only by pack animals, especially the camel, and even to-day this is the case over much of the region (Fig. 235). A number of caravan routes cross the Sahara, extending from oasis to oasis. The trade which originates or terminates in the Sahara is largely in dates, salt, clothing, cereals, and camels, while for centuries the through trade has included such things as ivory, gums, spices, and gold dust. Prince Henry of Portugal learned of the trans-Saharan trade while on an expedition against the Moors in northern Africa in 1415, and partly with the idea of diverting the trade of the Guinea Coast to his own country by water, he began the long series of explorations along the coast of Africa which culminated in the discovery of the all-water route to India. The use of the latter route to the East injured greatly the caravan trade across Asia. A trans-Saharan railroad is now projected.

Fig. 236. Date palms loaded with fruit. Biskra, Algeria.

Political conditions in deserts. The hard conditions of life in deserts repeatedly have driven their inhabitants out to conquer other regions (p. 333). On the other hand, the conquest of deserts from without always has been attended by great difficulties, and in some cases never has been accomplished. The love of freedom and the fighting ability characteristic of desert peoples, in addition to the difficulties which an invading army finds in the lack of roads, water, and food, have helped to produce this

result. Furthermore, the scant resources of deserts have made them relatively uninviting to outside people.

LIFE IN ARCTIC PLAINS

The plains which border the Arctic Ocean are known as *barren lands* in North America, and as *tundras* in Eurasia. They are *cold deserts*, snow-covered for some two-thirds of the year. The short summers, low temperatures, and cold or frozen soil prevent agriculture, and restrict vegetation chiefly to stunted bushes, mosses, and various quick-growing, flowering plants. The few, widely scattered inhabitants of the tundras depend largely on their herds of reindeer and on

Fig. 237. Reindeer and sledge.

hunting for their living. Fishing is an important occupation during the three or four months when the streams are free from ice. A nomadic life results from the necessity of following the game and the reindeer herds, which wander half-free in search of pasturage. As in the steppes and dry deserts, this nomadic life means small, easily transported dwellings — in many cases a tent consisting of a framework of poles covered with skins — and few and simple household goods. Some of the tribes move northward with their herds in the summer, and return to pass the winter in the forests which border the tundras on the south. Here the timber affords some shelter, feed is available for the reindeer, and game may be hunted for food and fur.

All that the camel is to the inhabitants of low-latitude deserts, the reindeer is to the men of the Arctic desert. It is indifferent to cold, and is an excellent draft animal (Fig. 237). Its milk and flesh are used for food; its bones and horns afford material for making various implements; its tendons and sinews serve for thread; and its skin is used for shelter and clothing. The reindeer is the most desirable form of wealth on the tundra. In some places, a herd of 50 head, which will support a family of four or five, requires between 4 and 5 square miles of tundra pasturage. This means at best a very sparse population.

Some years ago the United States Government imported nearly 1,300 reindeer from Siberia, for the benefit of the natives of northern Alaska. The herds have increased rapidly, and are proving of great value.

In the Arctic plains life is a constant struggle for food, clothing, and shelter. There is little opportunity for trade. Situated on the outskirts of the inhabited world, the frozen deserts of the north have played a much less important part in history than the centrally-located deserts of lower latitudes. Nor does it seem likely that they can become of much importance in the future.

Life in Humid Plains of Low Latitudes

Near the equator, the climate of the lowlands is characterized by heavy and frequent rains, and by high, nearly uniform temperatures throughout the year (p. 102). As we have seen, this results in a dense, varied vegetation (Fig. 238), like the forests of the Amazon and Congo valleys. The distinctive life of humid plains in low latitudes is therefore that of the tropical forest, or jungle. In some of the other realms which we have considered, man has been handicapped by lack of useful vegetation. Here, the very abundance of plant life is an obstacle to progress.

Response of natives to conditions in tropical forests. The dense forests of equatorial regions are occupied by sparse populations of backward natives. The high temperatures and the moisture are enervating, and steady work is difficult. The luxuriance of the natural vegetation makes the clearing of land difficult, and after it is cleared, a constant struggle is necessary to keep out the plants which are not wanted. Unused trails through the forest are overgrown quickly, and all trace of settlement soon disappears from abandoned clearings. Under these conditions, it is not strange that agriculture rarely is practiced. Throughout the world, man appears, as a rule, to have developed agriculture, or to have domesticated animals, only when the natural food supply became too small. In the equatorial forest, the natural food supply is abundant. The natives live

chiefly on the fish afforded by the many rivers, and such game as inhabits the forest. This is supplemented in many places by the products of certain forest plants, such as the sago palm.

The large animals found in many places in the open country near the tropical forests go into the latter only a short distance. They come and go through the denser growth by paths which they keep open by frequent passing. In the heart of the forest, there are few sources of food for animals near the ground. Flowers and fruits are found in the tree tops, however, and hence animal life is represented

Fig. 238. Tropical forest and river in flood. Southern Mexico. (W. L. Tower.)

chiefly by flying and climbing forms, such as insects, birds, snakes, and monkeys. Many of the birds and snakes resemble the foliage in color, a fact which favors concealment.

Little is needed by the inhabitants of the tropical forest in the way of clothing and shelter. Some of the lowest savages have no homes. Some of the people live in floating houses on the rivers, or in huts built on piles to escape the floods. Rivers are the most important lines of travel through the forest.

A little farming is done in clearings near the edges of the equatorial forests. In some cases, this consists in scarcely more than planting

crops, and leaving them to grow. Bananas, bread fruit, rice, and other things are grown in different places, chiefly by the women. Very little labor brings large returns, so that steady effort is discouraged. As in the equatorial forest generally, life is too easy; there is no spur to progress.

The Pygmies who live in parts of the Congo forest are perhaps the lowest type of human beings. Most of the adults are only a little more than 4 feet tall, and many are shorter. They make no attempt at farming, but live by hunting and fishing. They kill small game with arrows and spears tipped with a poison made from certain plants; and capture even large animals in covered pitfalls which they

Fig. 239. Pygmy village in the Congo forest.

make in the narrow runways followed by the animals (p. 338). They catch fish in nets or baskets. They live in small, scattered groups where there are openings in the undergrowth (Fig. 239), building temporary huts consisting in many cases of flexible sticks covered with leaves, and shifting from spot to spot in quest of game. They carry on some trade with other tribes, bartering meat, skins, and plant poisons, for weapons and vegetable food. The Pygmies have no arts save those connected with their hunting and fishing, and no family ties.

Commerce of tropical forests. The forests of tropical lowlands furnish products of much importance to the outside world, such as ebony, mahogany, rubber, gums, palm-oil, and copra. Trade follows the waterways, and in general those sections are most favored commercially which are situated conveniently with reference to a navigable river (p. 104).

The humid lowlands of the tropics are of far greater importance to man than the Arctic plains, but unfortunately the settlement and development of them by people from middle latitudes are attended with great difficulty (pp. 100, 103-104).

Questions

1. How might one prove that a given coastal plain was formerly a marginal sea-bottom?

2. By what are the characteristics (topography, fertility, etc.) of any given plain determined?

3. Why are the soils of most plains thicker and more fertile than those of plateaus and mountains?

4. (1) What great plains, now of little value to man, are likely to have greatly increased importance in the future? Why? (2) What ones are likely to continue of little significance? Why?

5. Compare and contrast the life of primitive peoples in arid deserts and rugged mountains.

6. How does the life of people in Arctic regions resemble that of desert tribes in lower latitudes?

CHAPTER XIX

COAST-LINES AND HARBORS

Importance of coast-lines. There is great freedom of movement over the ocean. A ship may sail direct from one port to another thousands of miles away, or it may make a roundabout voyage, calling at many ports on the way. A modern steamship can carry ten to twenty train loads of freight in a single cargo, and it costs far less to operate one steamer than to run ten or twenty trains. Furthermore, trains call for the maintenance of a railway, which is very expensive. Hence the carriage of freight by rail is much more costly than by boat. Modern commerce, therefore, depends much on the ocean highway, but it owes its rapid growth in part to favorable coast-lines through which access to the sea is secured.

In early days, seamanship was much influenced by the character of the coast-line. It was unsafe to go far from land, for vessels were small and there was no way of determining position accurately, or of reckoning distances. Hence seamanship developed first along the shores of quiet inland seas like the Mediterranean, or where long bays and sheltering islands invited ventures from one headland or island to another, as in Norway. Thus the first nations to become sailors, fishermen, explorers, and sea traders were influenced by the nature of their sea-coasts.

With modern steamships and skillful seamen, voyages are undertaken readily to distant parts of the earth. But even the giant steamship needs safe anchorage in quiet waters while its cargo is being loaded or unloaded. Some ocean commerce is carried on from places which have no harbor, but in such cases, vessels anchor off shore while the cargo is carried (*lightered*) from them to shore, or from shore to them, in small boats. During heavy seas lightering is impossible, and many wares cannot be handled to advantage in this way at any time.

Characteristics of coast-lines and their origin. If land along a coast were to be elevated or the sea-level lowered, a portion of

the sea floor would be exposed. Most of the sea floor is smooth and even. Hence the emergence of a coastal strip tends to make an even, regular shore-line (Fig. 240) fronted by shallow water. Coasts which have risen recently, relative to sea-level, are without good harbors, except where some large river, flowing across the coastal plain, offers a haven at its mouth. Commerce with such a coast is at a disadvantage. Large vessels must anchor off shore while their cargoes are lightered, unless artificial harbors have been made by

Fig. 240. Map showing regular outline of a newly elevated coast. Dotted lines indicate contours; interval 25 feet. (Nome, Alaska, Special Sheet, U. S. Geol. Surv.)

building breakwaters, jetties, or long quays. The east coast of India and most of the Gulf coast of Mexico present these conditions. Madras and Vera Cruz have artificial harbors because the trade from an important region justified the great expense involved in making a harbor.

The submergence of a coast land having hills and valleys produces a new shore-line which is irregular, the drowned valleys forming bays (Fig. 241). Isolated hills on the old lowlands may front the new coast as islands. The coast of Maine furnishes good examples. Such a coast-line commonly has many sheltered bays and harbors. Commerce is favored by such a coast. Most important commercial ports, such as the Atlantic ports of North America and Europe, are along depressed coasts. The chief sea fisheries, also, are connected with irregular coasts, partly because of the many convenient refuges

for fishing fleets. Not infrequently, also, large bays, like Chesapeake Bay, support valuable fisheries.

Where an irregular coast-line is produced by the sinking of a coastal plain, the bays may be wide (Why?), like Delaware and Chesapeake bays, but most of them are shallow, except along the line of the old river channel, and they may have marshy land along their borders. Few places on the shores of such bays are suitable for the development of a great port. Where a higher, more rugged region

Fig. 241. Map showing irregular outline of a depressed coast. Dotted lines indicate contours; interval 20 feet. (Monhegan, Maine, Sheet, U. S. Geol. Surv.)

is submerged, the bays are likely to be narrow and fiord-like, as in Alaska and Norway. Most of them are deep, and some are bordered by high land which rises so abruptly from the water that there is no room for a city.

Where the ocean finds access to an interior valley, a long inland arm of the sea, like Puget Sound, is developed. A former mountain pass in the Coast Range, now submerged, forms the picturesque Golden Gate entrance to San Francisco harbor (Fig. 242), and a little further sinking would change much of the central valley of California into a great sound.

Changes in shore-lines. Shore-lines are subject to constant change by waves, shore and tidal currents, rivers, winds, and ice.

The effect of glaciers on shore-lines has been noted (pp. 256, 261). Much of the value of Boston harbor depends on the protection afforded by islands of glacial origin. Shore ice has little effect on coast-lines, but hinders navigation along some coasts (p. 246).

Winds often make dunes on the sea shore (p. 202), and the dunes may afford the land some protection from the sea, as along the coast

Fig. 242. Diagram showing arm of ocean formed by invasion of valley through a submerged sag in mountain range. San Francisco harbor. Dotted lines indicate bar across entrance. (U. S. Coast and Geod. Surv., Chart No. 5500.)

of Holland, but they rarely change the outline of the land to any great extent.

Rivers affect shore-lines little by erosion, but delta-building rivers may change them greatly (p. 241). Other things equal, delta lands grow most rapidly in the quiet waters of bays and inland seas. Thus the delta of the Mississippi (Fig. 159) extends into the Gulf as a great irregularity, with many smaller irregularities about its borders. Delta-building in bays may lessen the irregularities of the coast by filling the bays. The value of Mobile Bay as a harbor is lessened because of the sediment deposited in it, and many others, which were important ports centuries ago, are now partly or entirely filled. The

city of Adria, Italy, once the port for the mouth of the Po, is now fourteen miles from the coast, and the Rhone delta, building forward at the rate of 200 feet a year, has never developed an important port (p. 270).

On exposed coasts, delta-building is less rapid (Why?), and produces fewer irregularities. The delta of the Amazon, for example, does not project beyond the general coast-line. Delta lands are low, marshy, and subject to floods, while the bays about their borders are shallow. For these reasons deltas are poorly suited to the development of ports, and except at the mouths of great rivers, like the Mississippi, deltas rarely become the sites of great commercial cities.

Fig. 243. Wave erosion of an exposed headland.

Waves are the chief agent changing coast-lines. On irregular coasts, the general tendency of waves is to wear away headlands (Fig. 243) and fill bays, thus making the shore more regular. On regular coasts, their general tendency is to wear back the shore-line. Waves therefore tend to destroy harbors. In many cases serious harm to commerce is prevented only by costly structures built to protect and improve harbors.

Waves are at work almost constantly on some part of every coast-line. Large waves are more powerful than small ones; hence coasts exposed to stormy seas are worn most, and those of loose material, such as gravel and sand, are cut back more than those of solid rock. The gravel, sand, and clay of the Atlantic Coastal Plain, and the glacial drift of parts of New England, are washed away more readily than the solid rocks of Maine or Norway.

In deep water away from shore, the water in a wave does not move

forward. An idea of its motion may be gained from a field of waving grain, where wave after wave crosses the field, though each moving stem is fixed to the ground. But when a wave advances into shallow water, its motion changes because the lower part of the wave drags bottom, and so is made to go more slowly. The top tends to pitch forward, making *surf* (Fig. 244). A somewhat similar effect may be produced in deep water when winds blow the tops of waves forward, forming *whitecaps*. Hence during storms, and especially in shallow

Fig. 244. Surf wave at Point Buchon, California.

water, there may be a distinct forward movement of the water in a wave, but generally in deep water it is only the wave motion, not the water, which travels forward.

In shallow water, the water which is thrown forward against the shore runs back down the slope of the bottom as the *undertow*. Drownings have resulted so frequently from bathers being caught by the undertow that many bathing beaches now have regular life guards constantly on watch during bathing hours.

If waves reach the shore obliquely, they produce a movement of water parallel to it. Such a movement is known as a *shore* or *littoral current*. Where a shore is exposed to winds prevailingly from one quarter, the resulting shore currents are somewhat constant in direction. Littoral currents are most important in moving the material worn from the land by waves.

Erosion by waves. The force of waves hurled against the shore may be very great. Surf has been thrown to heights of more than 100 feet with force enough to destroy lighthouses. The strength of waves on the coast of Great Britain is sometimes as much as three tons per square foot. Such waves are able to move masses of rock weighing several tons. During one storm more than 200 blocks of concrete, weighing 4 tons each, were swept from the break-water at Cherbourg, France, and tossed over an embankment. It is clear, therefore, that the force of waves is great enough to wear shores, even of solid rock. Where deep water is found near shore, as along most steep coasts, erosion depends on the work of the water alone. Where waves break in shallow water, pieces of rock may be hurled forward with the rushing water, and serve as powerful tools to cut away the land. In severe storms, the land is, in rare cases, driven back many feet in a few hours. The waves of lakes are never so strong as the great waves of the sea (Why?), but the storm waves of large lakes have great force, and may do much damage even in a single storm.

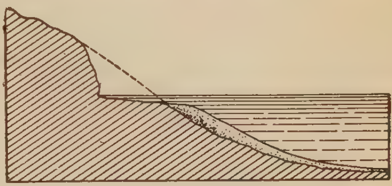


Fig. 245. A cliff fronted by a terrace. Outer (dotted) part of terrace built by deposition of sediment; inner part due to wave cutting.

The great force of waves on an exposed coast has led to many attempts in different countries to use wave power for industrial purposes. None of the devices yet tried has proved practicable on an important scale. One obstacle is the extremely variable character of the waves.

Fig. 246. Wave-cut terraces now well above the sea, indicating relative change in level of land and sea. Seward Peninsula, Alaska.

Where waves erode the land they make steep slopes, or *cliffs*. Such cliffs are bordered by *wave-cut terraces* a little below the surface of the water (Fig. 245). The width of such a terrace measures roughly the advance of the water on the land by the cutting of its waves. By rise of the land, or by sinking of the sea, the terrace may become land (Fig. 246).

By driving back sea cliffs, waves tend to increase the area of the sea at the expense of the land. The island of Heligoland, off the German coast, has been so worn by waves that it is less than one-twentieth as large as it was a thousand years ago. Many shoal areas off the New England coast are due to the cutting away of small islands.

Fig. 247. Wave-cut cliff with some of the material left in the form of a beach at its base. Lake Michigan.

Deposition by waves and shore currents. Material worn from the land by waves, or brought to the shore by rivers, is shifted about by waves, undertow, and shore currents, but finally comes to rest. If left at the shore-line it makes a *beach* (Fig. 247). If carried farther out into the water, it takes on other forms. Fine particles of mud generally are carried out into deeper water, while coarser material, such as sand and gravel, make the beach.

Waves may build *reefs* or *barriers* a little way out from the shore. They are formed near the line of breakers, where the incoming wave leaves much of the sediment which it is moving toward the land. The undertow may add to the reef by carrying sediment out from the shore. Some reefs are troublesome to navigation, especially where they make "a bar" at the entrance to a harbor.

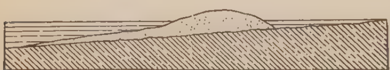


Fig. 248. Diagram representing a cross-section of a barrier beach.

Waves may build the crest of a reef above water, converting it into land (Fig. 248). By building dunes, the wind may then aid in raising the surface still higher. This seems to have been the origin of many low, narrow belts of sandy land parallel to coasts, with marshes and lagoons behind them. Such barriers are common in shallow water, as at many places from New York to Texas. Lagoons behind reefs provide harbors in some places.

Where a shore current reaches a bay, it does not, as a rule, follow the outline of the bay, but tends to cross it in the direction in which it had been moving. Under such circumstances it may build an embankment or *spit* of gravel and sand near the entrance to the bay. Currents do not build spits above the water, but waves may build them up into land by washing material from their slopes up to their tops. After they become land, the wind may build dunes on them (Fig. 251). When spits (Fig. 249) cross bays they become *bars*. Along some coasts, as on the south side of Martha's Vineyard Island, such bars have closed the entrances to many bays.

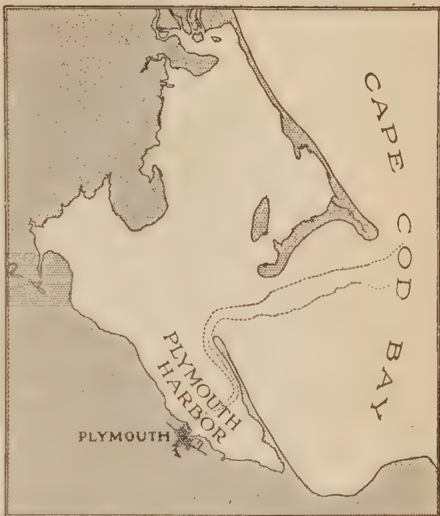


Fig. 249. Map of harbor formed by spits; Plymouth, Mass. Broken lines show approximate limits of channel. (U. S. Coast and Geod. Surv., Chart No. 110.)

Reefs, spits, and the land to which they give rise, increase the irregularity of the coast-line for a time; but they represent the first step toward regularity, for, after the reefs have become land, the lagoons behind them are likely to be filled with sediment washed down from the land or blown in by the wind (Fig. 250).

Fig. 250. A barrier beach with marshy tract (filled lagoon) behind it. Lasells Island, Penobscot Bay, Me.

Deposits of gravel and sand may be made between a mainland and islands near it. The Rock of Gibraltar, on the coast of Spain, has been thus "tied" to the mainland.

Bars and reefs may hinder the movements of vessels, especially where they tend to close the entrances of harbors. A spit which does not obstruct the entrance to a harbor is sometimes an advantage, since it breaks the force of incoming waves. Spits which form harbors have determined the location of numerous villages and cities. The harbor of Plymouth, Mass., for example, is protected by a spit which makes a natural breakwater (Fig. 249). Provincetown, Mass., and Erie, Penn. (Fig. 251), have harbors made by curved spits.

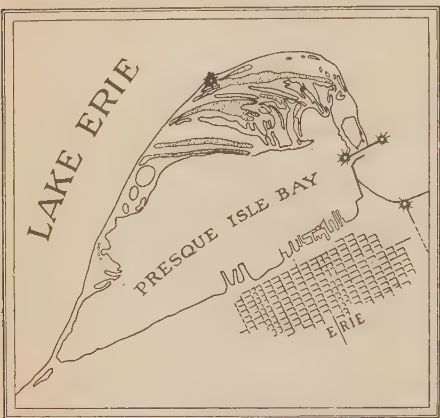


Fig. 251. Map of harbor formed by curved spit; Erie, Penn. Dotted areas are lines of sand dunes. (Erie, Penn., Sheet, U. S. Geol. Surv.)

Harbors. Harbors vary greatly in value. A good harbor must, first of all, afford shelter from stormy seas, must be deep enough for large vessels, must be connected with the open ocean by a deep channel, and must provide room for many ships. The direction whence the storm waves come and the direction which the harbor entrance faces have much to do with its safety. A harbor with a wide, unprotected entrance, facing the south, may be a good haven on a coast where the storm waves come from the east or northeast. The harbor of Gloucester (Mass.) illustrates this condition. The straighter and wider the channel leading into the harbor, the better, for long vessels cannot navigate safely a narrow, winding channel. This fact alone made it necessary to open a new entrance (Ambrose channel) to New York harbor. The water near the shore should be deep enough to permit vessels to reach the docks, and the shore should be suitable for landings and port facilities. A good harbor should be free from ice.

A harbor may have all these qualifications and yet be of little value commercially. Thus Casco Bay, Maine, is said to be one of the finest

havens in the world, but Portland is one of the lesser Atlantic ports. For commercial importance (Figs. 252 and 253), a harbor must have good lines of transportation either to a large producing region, or to one which requires many wares from the outside world. Thus New York is first among Atlantic ports, not so much because of a better harbor, as because of its better connections with the interior, where many articles of commerce are produced and consumed. As a whole, the Pacific coast of the United States is less important commercially than the Atlantic coast, partly because of the broad deserts and high mountains which lie behind it (p. 401).

Harbors at the mouths of large rivers are likely to have easy communication with the interior through river navigation, and the valleys are natural routes for railways. Thus important ports, like New Orleans (Figs. 252 and 253), Para, Calcutta, and Rangoon, are near the mouths of rivers which serve as highways of trade. River-mouth harbors, however, have many disadvantages. The current is a handicap for sailing vessels, which are still important in coastwise commerce. Many large rivers, like the Mississippi, Amazon, and Ganges, have large deltas, on which the stream breaks up into distributaries, whose mouths may be blocked by deposits of silt and mud. Shallow water is common near the entrances, and this disadvantage increases as larger vessels are built. Not infrequently the main discharge of the stream shifts from one mouth to another. In many rivers winding channels are kept open only by building jetties to direct the current.

For these reasons expensive work has been undertaken in some cases, such as the building of the Eads jetties at the Southwest Pass from the Mississippi, in order to keep one mouth open and deep at all times. In other cases, the port developing in connection with a river has been located at the nearest favorable place, free from the disadvantages of the river mouth. Thus Marseilles is about 30 miles from the mouth of the Rhone, and Kurachi is some 15 miles from the mouth of the Indus. In each case, connection with the river, inland, is made by rail.

Most of the important harbors of the world have been made by the submergence of river valleys. The harbors of New York, Philadelphia, San Francisco, Seattle, Liverpool, London, Hamburg, Shanghai, and hundreds of others belong to this class. The embayed river has many advantages over such a stream as the Amazon, as the place for a commercial center. The entrance rarely shifts, is likely to be deep, and not infrequently tidal currents prevent its being filled by sediment. Water navigation also may be possible

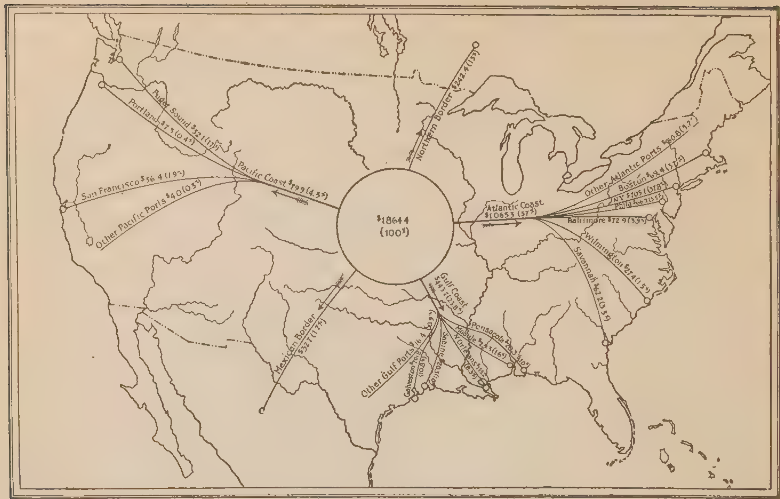


Fig. 252. Diagram showing movement of exports from the United States by coasts and leading ports, 1910. Values are expressed in millions of dollars. Percentages refer to proportion of total trade.

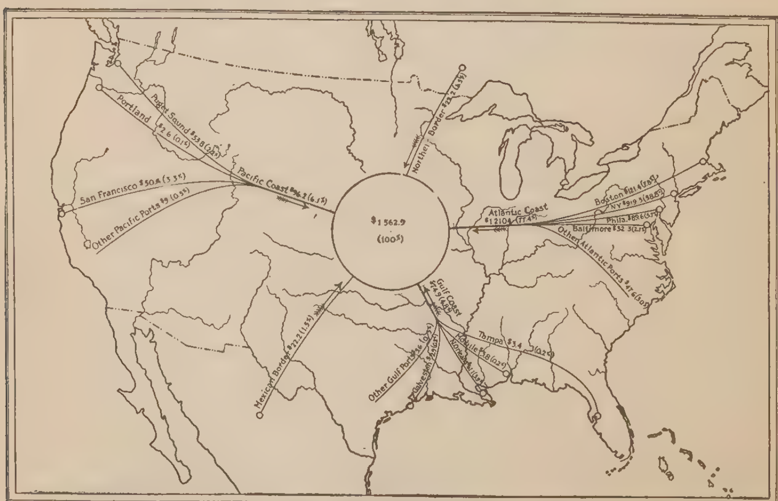


Fig. 253. Diagram showing movement of imports into the United States by coasts and leading ports, 1910. Values are expressed in millions of dollars. Percentages refer to proportion of total trade.

for some distance inland. Thus boats can go from Shanghai far into the interior of China (p. 269), and Hamburg benefits from a water route which reaches the Austrian frontier.

Many harbors on embayed coasts are affected by the deposition of sediment in or across their entrances (Fig. 254). The direction in which the entrance opens, with respect to the movement of shore currents, is important in this connection. Thus the embayed mouth of the Housatonic River receives the material drifted westward by the shore currents of Long Island Sound. As a result its entrance is very shallow, and the river mouth has no important port. New Haven harbor, on the other hand, is so situated that the shore current is turned away from the entrance toward deeper water. Its entrance is deep enough for the passage of good-sized vessels, and partly for this reason New Haven early became an important shipping center. On some coasts where harbors occur only at rather long intervals, jetties have been built to overcome the action of shore currents (Fig. 255). Galveston harbor has been improved in this way.

Fig. 254. Map of river mouth with shallow water over the bar at the entrance; Calcasieu Pass, La. Dotted lines indicate 6 foot depth. Broken line indicates 12 foot depth. Figures give depth in feet. The channel across the bar changes with every gale, so that strangers are warned not to enter without a pilot. (U. S. Coast and Geod.Surv.,Chart No.202.)

Fiords are numerous along some coasts, but they are relatively unimportant as sites for large ports, partly because many fiords are in high latitudes where commerce is not very important, and partly because of the character of the fiords themselves. Many are too deep for anchorage in the main channel, their land borders are too steep and high for the growth of a large port, and they are associated in many cases with mountains which hamper communication with the interior (Fig. 176). The quiet upper waters of fiords, however, afford good protection from storm waves, and every primitive people occupying a fiord coast early developed the sea-going habit.

Lagoon harbors may be produced by the formation of barriers, or by the growth of coral reefs. The former are numerous along the

Atlantic and Gulf coastal plains, but, except where combined with sunken coast-lines, few attain commercial value. The water off shore is rarely deep, most of the inlets are narrow and shallow, and many have such strong tidal currents as to prevent the ready passage of small craft. The inlets also may be closed by sediments deposited by waves and currents, unless protected by artificial works. The lagoon, even if deep originally, or dredged to a satisfactory depth, tends to become shallower through the deposition of sediment. Most lands bordering lagoons are low and marshy on the mainland side, with only a low, sandy island, exposed to winds and waves, on the ocean side. Neither is well fitted to be the site of a great port. Galveston is the best example of a port with a lagoon harbor; large sums have been spent to develop and maintain both the harbor and the city. Lagoon harbors due to coral reefs or atolls are fairly numerous in tropical waters, especially in the South Pacific, but are of little importance, because most of them are associated with small islands, which have little commerce. The Great Barrier Reef of Australia harms rather than helps the commerce of that country.

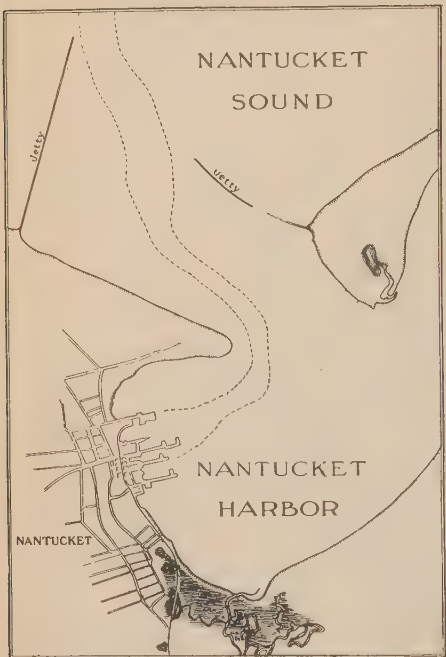


Fig. 255. Map of harbor maintained by jetties; Nantucket, Mass. Broken lines indicate approximate course of channel. (U. S. Coast and Geod. Surv., Chart No. 111.)

Few harbors are suited naturally to all the demands of present-day commerce. Crooked channels must be straightened, and narrow and shallow channels must be dredged. The opening of the Ambrose channel in New York harbor is an example. This new entrance to the leading Atlantic port of the United States involved the improvement of an old channel which had a depth of only 16 feet at low tide.

This depth was enough for light-draft vessels, like scows and towboats, but the need for a better entrance led to the deepening and widening of the channel so that it now has 40 feet of water at low tide, and a width of 2,000 feet for a length of seven miles. The work was done by powerful dredges at a cost of about six million dollars. In a single year more than 600 trips were made by vessels of such size that, before the opening of the new channel, they could have entered only by lightering, or by waiting for very high tide. The channel from Philadelphia to the sea must be dredged to a depth of 35 feet in order to admit the largest ocean vessels. A plan is on foot to make a new port at the eastern end of Long Island, to accommodate steamers having such a length that docking facilities are no longer convenient in the limited space along the New York water front.

In many places the demands of commerce from lands bordered by regular coasts compel the spending of large sums for artificial harbors. Dover, England, has one of the greatest artificial harbors in the world. There a series of concrete breakwaters more than two miles long enclose a harbor of nearly one square mile, with a minimum depth of 40 feet. The harbor cost more than $20,000,000. Its chief value is as a base for naval vessels at a strategic point on the English coast. A breakwater nearly two miles long has been built at Hilo, Hawaii, to protect shipping from the northeast trades. Similar extensive additions have been made recently to the works at Madras, to make that port equal to the other commercial centers of India.

To keep pace with the ever-increasing demands of commerce, large appropriations are made annually by our federal government. From the standpoint of commerce, harbor improvement is one of the most important phases of government work.

Many ports once important have declined because of the changing conditions of commerce. Thus the discovery of the all-sea route to India in 1497 shifted the main scene of commerce from the Mediterranean to the Atlantic coast of Europe. Mediterranean ports, like Venice, declined to such an extent that they almost ceased to be factors in the handling of European commerce. The opening of the Suez Canal (1869), however, made the Mediterranean the shortest route for trade between western Europe and the Orient; it led to a great expansion in the volume of commerce between those regions, and gave a new stimulus to Mediterranean ports.

A similar condition is found in the Caribbean Sea and the Gulf of Mexico. These bodies of water bear to the Atlantic and the Americas a relation resembling that borne by the Mediterranean to the same ocean and the continents of the Old World. Here also a narrow isthmus blocks communication with the Pacific. The Panama Canal, however, will open this route. By shortening the distance from our Atlantic ports to most Pacific points, it will make the Caribbean a more important highway, and lead to increase of trade between the two oceans. The neighboring ports, like those along

the Gulf coast of the United States, will be stimulated by new traffic destined for Pacific points; they are also likely to benefit much as handling centers, on account of their position as way-stations between the populous countries of the East and West. Many Pacific ports will be benefited similarly by freer communication with the Atlantic.

Questions

1. Why is Holland better situated than Belgium for carrying on sea trade?

2. Why are the natives of the Malay archipelago expert boatmen?

3. Why is the location of Montreal better than a place at the entrance to the Gulf of St. Lawrence for the development of a seaport?

4. What dangers threaten vessels plying along submerged coasts? Along recently elevated coasts?

5. How would a submergence of 500 feet affect the Mississippi River system?

6. How can the direction of shore currents be determined from the outline of the coast? Explain in the case of Cape Cod.

7. Why are there few important commercial centers on the coast between Cape Henry and Cape Florida?

8. What prevents Portland, Me., from being a leading commercial center?

9. Classify the leading seaports of the United States according to the kinds of harbors which they possess.

10. Why are some harbors in tropical regions, as Manila harbor, well protected at one season and not at another?

11. Which Gulf ports are likely to benefit most from the opening of the Panama Canal? Why?

12. Why would fishing villages be more likely to develop along the coast shown in Fig. 241, than along that shown in Fig. 240?

13. Suggest the probable course of shore currents along the coasts shown in Figs. 251 and 255. Which harbor is likely to be affected the more seriously by shore currents? Why?

14. Suggest reasons why New York is a great exporting and importing city, and why Galveston exports much but imports little.

CHAPTER XX

DISTRIBUTION AND DEVELOPMENT OF THE LEADING INDUSTRIES OF THE UNITED STATES

Agriculture

Importance of agriculture. Agriculture is the most fundamental industry of the United States; it furnishes, directly or indirectly, most of what we eat and wear, and other needs are less important than food and clothing. More than ⅓ of the wage-earners

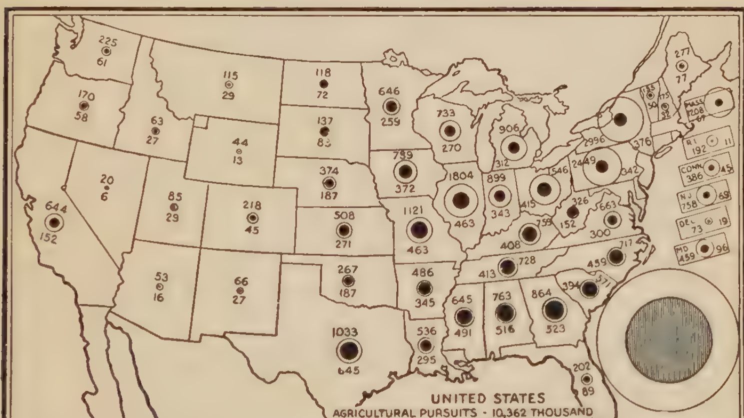


Fig. 256. Wage-earning population in agricultural pursuits in each state in 1900 shown by inner black circle, and by the smaller number adjacent; wage-earning population in all pursuits shown by the outer ring, and by the larger number adjacent. Numbers = thousands of wage-earners. (After Middleton Smith.)

of the country are engaged in agriculture (Fig. 256). The total value of farm lands increased about ⅓ between 1900 and 1905, and in 1910 amounted to more than $28,000,000,000. About half the farm lands, or approximately one-fourth the area of the country, is cultivated.

Fig. 257 shows the relation of improved acreage to total farm acreage (including woodlots, etc.) in the different states.

The total value of all farm products has increased each year for more than a decade, and reached nearly $9,000,000,000 in 1910.

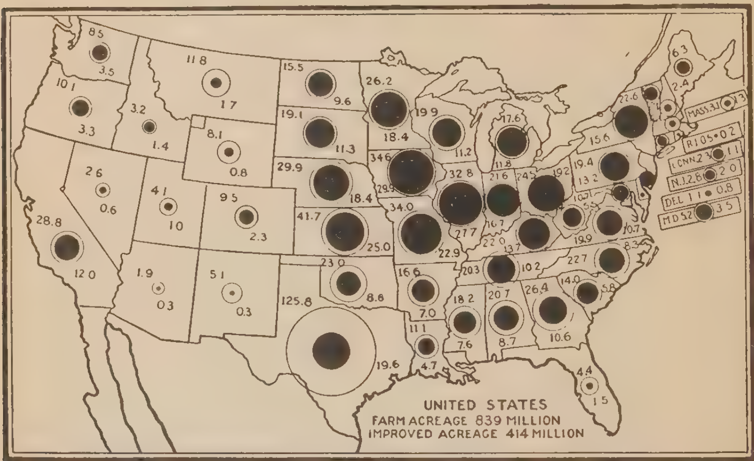


Fig. 257. Map showing relation of improved acreage (black circles) to total farm acreage (outer rings) in the different states in 1900. The smaller numbers adjacent to the circles = millions of acres of improved land; the larger numbers = millions of acres of farm land. (After Middleton Smith.)

This was more than double the figure for 1900 (Fig. 258). In 1910, the six crops leading in value were corn, cotton, hay, wheat, oats,

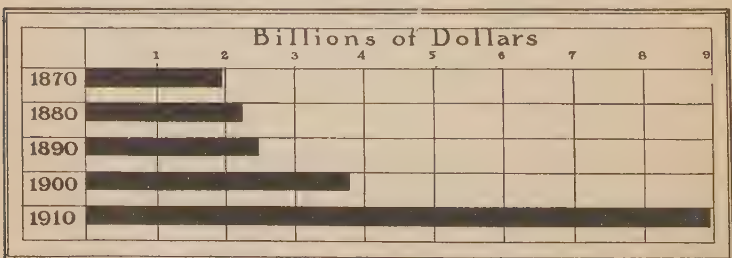


Fig. 258. Diagram showing total value of farm products in the United States for the census years 1870–1910.

and potatoes. The United States produces about 4/5 of the corn of the world, 3/5 of the cotton, 1/4 of the oats, and 1/5 of the wheat.

The leadership of the United States in agriculture is due to (1) the extent, variety, and high average fertility of its soils; (2) the favorable climate of most sections, with range sufficient to favor the production of many crops; (3) the facilities for marketing products; (4) the energy and ability of the farming people as a whole; and (5) the activity of federal and state agencies in introducing new plants, better seeds, and scientific methods of cultivation.

Leading Crops

The general distribution of crops throughout the United States is controlled largely by climate (pp. 119, 121, 127, 131). Their detailed distribution is influenced also by soil, topography, transportation facilities, market conditions, and other factors. It is practicable to consider here only the leading crops.

Corn. Corn is our most important crop — in total value, acreage, and amount grown. More than 300 varieties of corn are

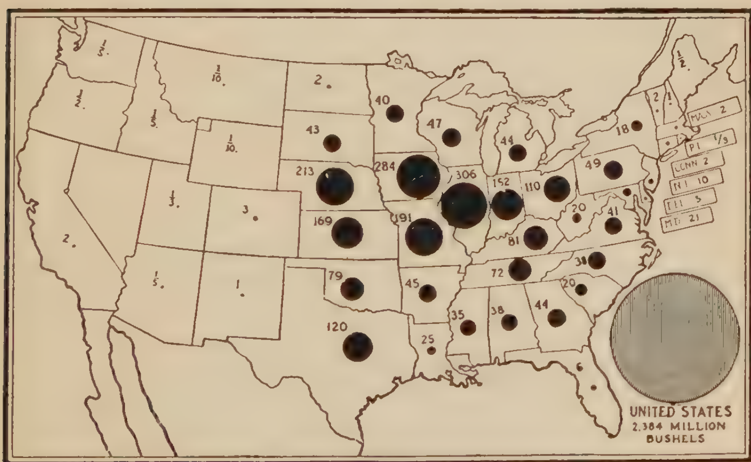


Fig. 259. Average annual production of corn in the different states (1899–1908). Figures in states represent production in millions of bushels. (After Middleton Smith.)

known, but only a few are grown in large amount. The leading varieties thrive best where there are plentiful rains with prevailingly warm, sunny weather during the growing season, and in rich, well-drained soils. The "corn belt" is south of the "wheat belt," be-

cause the staple varieties of corn require a higher temperature and a longer warm season. Illinois, Iowa, Nebraska, Missouri, Kansas, and Indiana are the leading corn-producing states (Fig. 259). The average yield of corn per acre is about 25 bushels. Experiments show that this can be doubled at least by the general adoption of better methods of tillage, careful selection of seed, and the use of varieties best suited to the places in which they are grown. During the last five years the corn crop of the United States has averaged nearly 2,700,000,000 bushels.

Because of the low price of corn, compared to its bulk and weight, little is shipped to distant markets. Most of it is used where it is grown, to feed stock. Corn is used also as a breadstuff, and in the manufacture of whiskey (p. 389), glucose, and other products.

Corn appears to be a native of the highlands of Mexico, whence its cultivation spread northward and southward at an early date. The colonists found it cultivated more or less by many of the Indians, and in many cases they promptly began to grow it. A number of the successful English settlements of eastern United States probably would have failed but for this food plant. As settlement spread westward, corn was the staple crop of much of the frontier. It was easy to cultivate, and usually returned a relatively large yield. It was stored easily, easily prepared for food, and was nourishing both for animals and man. "The progress of our conquest of this continent would have been relatively slow had it not been for the good fortune which put this admirable food plant in the possession of our people."

Wheat. In the United States, wheat is the most important food plant. It probably originated and was cultivated first in Mesopotamia, but its culture spread in prehistoric times into other parts of Asia, and into Europe and North Africa. Its great value as food, the comparative ease with which it can be transported (Why?), and its power to adjust itself to new conditions, favored its wide and rapid dispersal. As a result of long cultivation and selection under different conditions, there are now more than 1,000 varieties of wheat, adapted to rather diverse conditions.

Wheats are commonly classified as *spring* and *winter wheat*, *red*, *white*, *hard*, and *soft*. In the northern interior states spring wheats chiefly are grown, for plants from seeds sown in the fall are "winter-killed"; farther south, much winter wheat is raised. In general, soft wheats, relatively rich in starch, are used in making flour, while the very hard kinds, rich in gluten, are used chiefly for the manufacture of macaroni (p. 128). The last is especially true of the durum wheat grown in the western Great Plains (p. 173). Hard and soft varieties are commonly mixed in making flour. The chief white wheat district is in the Pacific coast states.

Fig. 260 shows the average annual production (1899–1908) of wheat in the different states. The total wheat crop of the country in 1911 (more than 650,000,000 bushels) was nearly

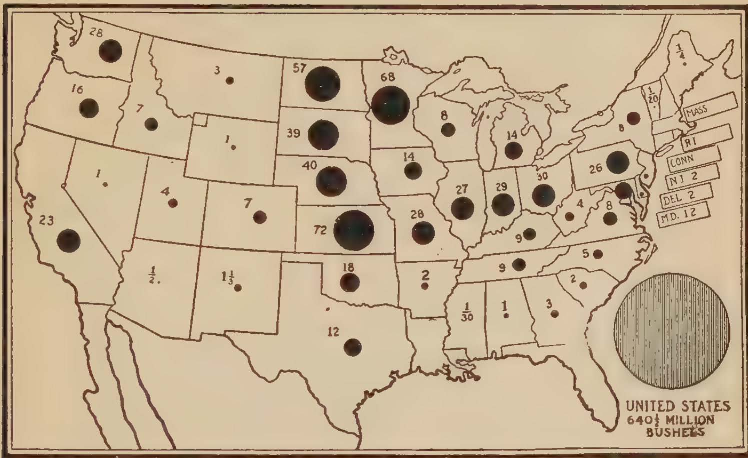


Fig. 260. Average annual production of wheat in the different states (1899–1908). Figures in states represent production in millions of bushels. (After Middleton Smith.)

seven times as great as that of 1850. This increase was due to (1) the demands of the increasing population, (2) the occupation of new areas suited to wheat culture, (3) the improvement and general use of farm machinery, and (4) the improved conditions for storing, transporting, and milling the grain. As in the case of most other crops, the average yield per acre of wheat in the United States can be increased greatly. For

Fig. 261. Map showing centers of production of corn, wheat, and oats (1850–1900).

the ten years 1897 to 1906, inclusive, it was 13.8 bushels; during the same time it was 32.2 bushels in the United Kingdom, 28 in Germany, and 19.8 in France. During recent years the exportation of

wheat from the United States has decreased, as the demands of the home market have increased. While the acreage devoted to wheat culture in the United States can be increased in the semi-arid sections, and wheat may be imported, the greater supply needed in the future must be obtained chiefly by securing larger yields where wheat is already grown. The centers of cultivation for wheat and the other leading cereals have moved steadily westward (Fig. 261).

Other cereals. *Oats* thrive best in a moist and relatively cool climate. They do fairly well in some of the southern states, where the climate, though warm, is moist, but do not grow well where it

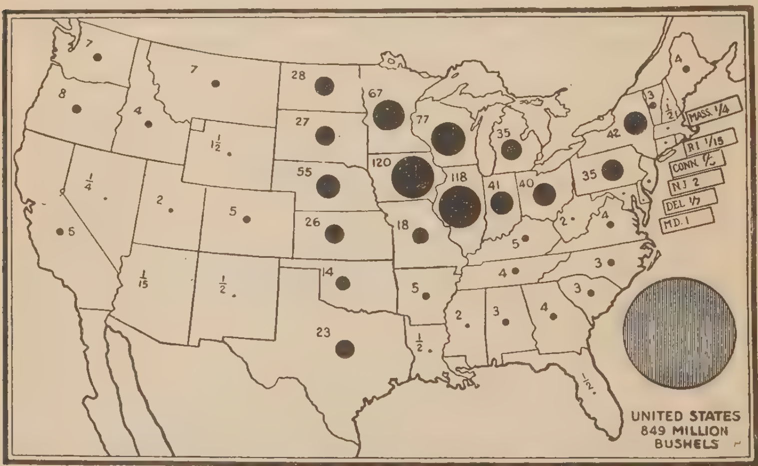


Fig. 262. Average annual production of oats in the different states (1899–1908). Figures in states represent production in millions of bushels. (After Middleton Smith.)

is both warm and dry. The chief area of production is in the northern Interior (Fig. 262). In recent years the total oats crop of the country has averaged nearly a billion bushels. A small part of the crop is used as food for man, chiefly in the form of oatmeal; most of it is used as feed for animals.

Although *barley* can be grown successfully under a wider range of climatic conditions than either wheat or corn, its cultivation in the United States is confined largely to the region west of Lake Michigan (from Wisconsin to the Dakotas), and to the Pacific coast. In the order of their importance, the leading states are California,

Minnesota, Wisconsin, North Dakota, Iowa, South Dakota. In the northern Interior the barley is used chiefly for the manufacture of malt liquor (p. 389), and on the Pacific coast for feed.

Among the minor cereals grown in the United States for their grains or for forage are *rice* (Fig. 263), *rye*, *buckwheat*, *kaffir corn*, and *millet*.

Hay. Hay includes various grasses and legumes which are "cured" as food for stock. The more important ones are timothy, clover, and alfalfa (p. 297). Some of the cereal grasses, like oats and barley, sometimes are grown for hay. Hay is produced in every

Fig. 263. Average annual production of rice in different states (1904–1908). Figures represent production in thousands of pounds. (After Middleton Smith.)

state, but the chief area is in the eastern half of the country, north of the 37th parallel. Although alfalfa is cultivated chiefly in the western part of the country, it probably will become of importance in the middle states in the near future, because of its relatively large yields, its high nutritive value, and its importance in increasing the amount of nitrogen in the soil (p. 29).

Cotton. The cotton of commerce is the fiber which surrounds the seeds of the cotton plant. The value of the fiber and the uses to which it is put depend on its length (½ to 2½ inches), strength, fineness, and color. The cotton plant requires a warm, moist climate, and a relatively long season free from frost. These are the principal factors which limit the cotton-producing area of the United States to the southern part, east of the Great Plains (Fig. 264). In some other countries, the area of cotton culture may be extended. *Sea-island cotton*, characterized by its long, fine fiber, thrives best on certain islands off the South Atlantic coast, partly because of the high

humidity. Sea-island cotton is also grown some distance inland in southern Georgia and northern Florida. In general, the largest yields of cotton are obtained on the alluvial soils of the valley bottoms, and on the limey soils of the coastal plain (p. 171). During the last five years the total cotton crop of the country has averaged more than 12,000,000 bales. About ⅓ of the cotton grown in the United States is manufactured at home (p. 387); the rest is exported.

The cultivation of cotton in the United States began in the colonial period, but increased slowly until after the invention of the cotton gin (Eli Whitney, 1792) in this country, and of spinning machinery in England. The former made easy the separation of the fiber from the seed, enabling one man to do as much as 100

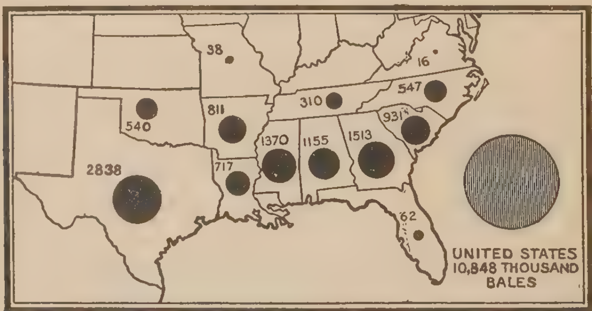


Fig. 264. Average annual production of cotton in different states (1899–1908). Figures represent production in thousands of bales. A bale is 400–500 pounds. (After Middleton Smith.)

to 200 could do by hand. These things, coupled for some years with unusually high prices for cotton, caused a great increase in its production. The development of the cotton industry meant also a greatly increased demand for slaves as field hands. The work in the cotton fields was simple, requiring little skill and few tools. In these and other ways it was adapted to slave labor, and, as years passed, cotton culture and slavery became mutually dependent. They became, too, dominant factors in the economic, social, and political life of the southeastern states, and helped to separate their interests in many ways from those of the northern states. Thus, the New England cotton manufacturer (p. 387) demanded a tariff on imported goods to protect him against foreign competition; the southern cotton planter, who bought many of his supplies abroad, was injured by the tariff, and of course opposed it. The growing sectionalism between the North and South resulted in the Civil War.

Other vegetable fibers. Of the several plants besides cotton which are grown for fiber, only hemp and flax are cultivated to any large extent in the United States. Indeed, the latter is cultivated

here almost entirely for its seed, from which linseed oil is obtained. In Russia and some other places, flax is produced chiefly for the inner bark fiber, from which linen cloths are made. The fiber of hemp is used to make twine, rope, bagging, etc. Although both plants can be grown under rather a wide range of conditions, the cultivation of hemp in this country is confined largely to Kentucky, and that of flax chiefly to the Dakotas, Minnesota, and Montana.

Tobacco. The United States produces about 1/3 of the tobacco of the world, its crop in 1911 being about 800,000,000 pounds. It is grown in most states east of the 97th meridian, but a few produce the bulk of the crop (Fig. 265). The quality of the product varies greatly with the conditions of soil and climate, and with the care used in selecting the seed, cultivating the plants, and curing the leaves. Many grades are produced.

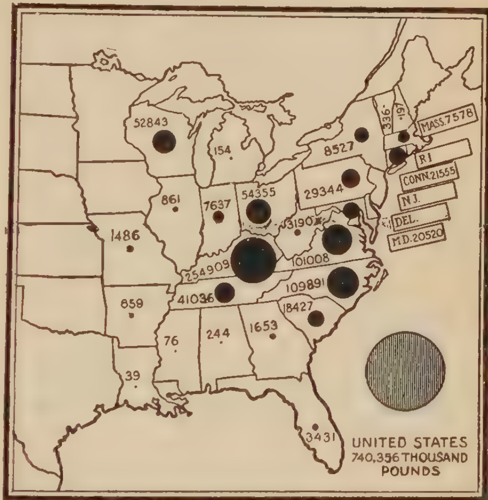


Fig. 265. Average annual production of tobacco in different states (1900–1908). Figures represent production in thousands of pounds. (After Middleton Smith.)

Vegetables and fruits. The growing of vegetables and fruits for distant markets and for food throughout the year has become an important industry mainly as a result of (1) improved transportation facilities, especially refrigerator cars, and (2) the development of the canning industry (pp. 379, 386). It is impracticable to consider here the many fruits and vegetables now grown for commercial purposes in the United States. Some have been mentioned (pp. 119, 297, 298). Potatoes rank first in value among vegetables, and apples among fruits; the cultivation of both is distributed widely.

The influence of refrigerator cars on the rise of industries involving the shipment of perishable foodstuffs has been very great. The fruit and vegetable industries of the South and the deciduous fruit industry of the far West owe their

development largely to the refrigerator car. It has enabled California, though one of the states farthest from the chief city markets, to become the leading fruit-growing state (p. 297).

In many places, the refrigerator car helped change various fruits and vegetables from luxuries, obtainable during a short season only, to staple articles of food available during a long season, or throughout the year. For example, New York City formerly obtained cantaloups during a few weeks only from New Jersey, Delaware, and Maryland. Now the season for them in New York lasts from early May to late October, and some of them come from the Pacific coast.

Sugar plants. Sugar-cane is a tropical and sub-tropical plant, and its cultivation in the United States is confined to the Gulf States, Georgia, and South Carolina. Louisiana grows more than 9/10 of the total crop of the country. In 1911, 690,000,000 pounds of cane-sugar were produced in the United States.

The sugar-beet was brought to this country some forty years ago from central Europe, and in recent years its cultivation has spread rapidly. California, Michigan, Colorado, Utah, Idaho, and Wisconsin lead in the production of sugar-beets, but the industry has some importance in a dozen other states. In the West, sugar-beets are grown largely on irrigated lands. The production of beet-sugar in the United States increased about sixfold between 1900 and 1911, amounting, in the latter year, to more than a billion pounds.

Animal Products of Farm and Range

Cattle. Cattle are raised in the United States chiefly for beef, dairy products, and hides. Fig. 266 shows that most of the milch cows are in the more densely settled eastern half of the country, and that in the eastern half, most are in the northern states. The many cities and villages of the North Atlantic and North Central States require an enormous quantity of milk, and cannot draw their daily supplies from great distances. Herds may be kept at a greater distance from market in connection with the manufacture of butter, cheese, and condensed milk (p. 386).

Fig. 267 indicates the distribution of cattle other than milch cows. This map differs from the preceding one in the smaller numbers for the North Atlantic States and the greatly increased numbers in the Great Plains and western states. Large parts of the Great Plains afford the best environment for cattle in the country, and much of the land, furthermore, cannot be used for growing crops (p. 329). Extensive areas are required for grazing

large herds of cattle, and with the growth of population in the East much land so used in earlier years has been devoted to other purposes. The United States has about $^1/_7$ of the world's cattle.

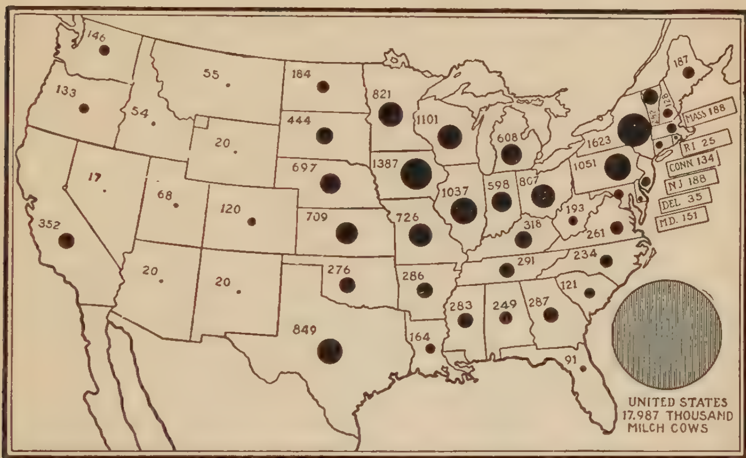


Fig. 266. Milch cows on farms and ranges. Average annual number in thousands (1899–1908). (After Middleton Smith.)

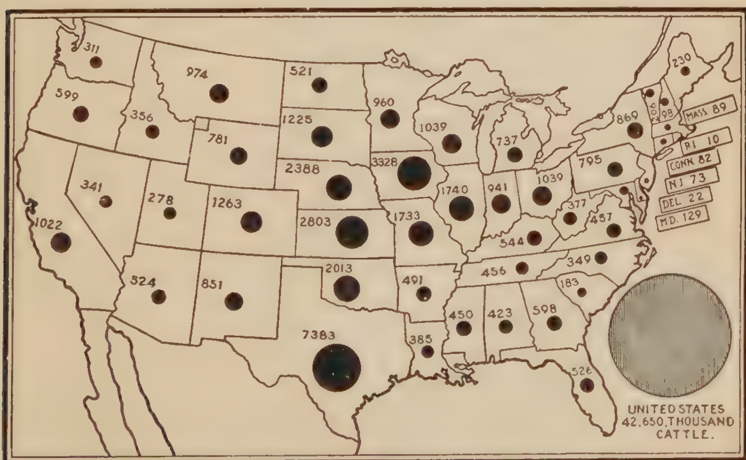


Fig. 267. Cattle other than milch cows on farms and ranges. Average annual number in thousands (1899–1908). (After Middleton Smith.)

Sheep. Sheep are raised for mutton and wool. During the last fifty years a great change has occurred in their distribution. The number in most of the middle and eastern states has decreased, while in the western states it has increased greatly. At the beginning of the period, the West had less than $^1/_{10}$ of the sheep of the country; now it has more than $^2/_3$ (Fig. 268; What are the probable reasons for the change?). The annual wool clip of the United States is more

Fig. 268. Sheep on farms and ranges. Average annual number in thousands (1899–1908). (After Middleton Smith.)

than 300,000,000 pounds; nearly all of it is used in American factories, and in addition much is imported.

Swine. About $^2/_5$ of the swine of the world are in the United States. While they are raised more or less in every state, the great swine region (Fig. 269) is the same as the leading corn-producing section (Fig. 259), for corn is the chief food for swine. Nearly half the corn crop is disposed of in this way.

Horses. A comparison of Fig. 270, showing the distribution of horses in the United States, with Fig. 257, showing the improved acreage and its relation to the total farm area in the different states, indicates that the number of horses in the different states corresponds roughly to the amount of land cultivated. This is less striking in some of the southeastern states, where many mules are used to cul-

tivate the land, because they can stand hard work in that climate better than horses.

The total value of farm animals in the United States in 1910 was about $5,000,000,000.

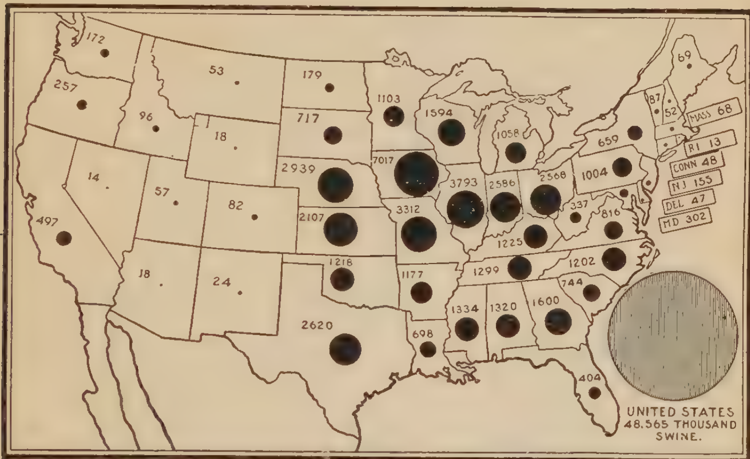


Fig. 269. Swine on farms and ranges. Average annual number in thousands (1899–1908). (After Middleton Smith.)

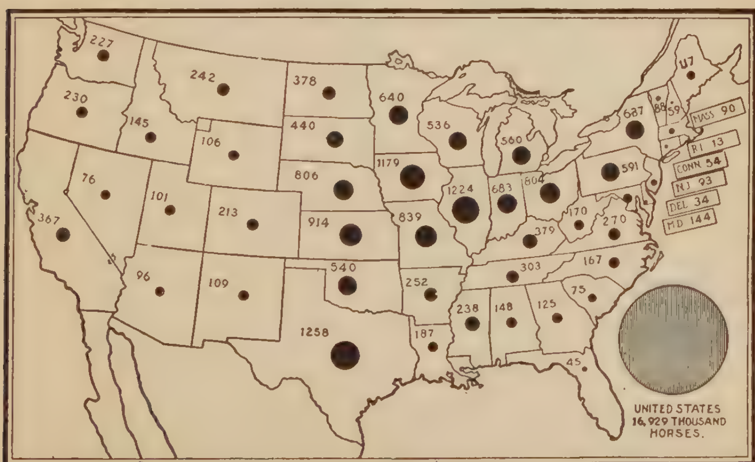


Fig. 270. Horses on farms and ranges. Average annual number in thousands (1899–1908). (After Middleton Smith.)

Poultry and eggs. Poultry and eggs are incidental products of most farms. In recent years poultry-raising has become also a specialized industry of importance, particularly in the leading corn-producing states and near some of the larger cities. The value of the poultry and eggs produced yearly in the United States is nearly $300,000,000.

Forest Resources and Lumbering

The forests of the United States have been a chief factor in the progress of the country. They have furnished firewood and materials for buildings, furniture, implements, utensils, vehicles, fences, paper,

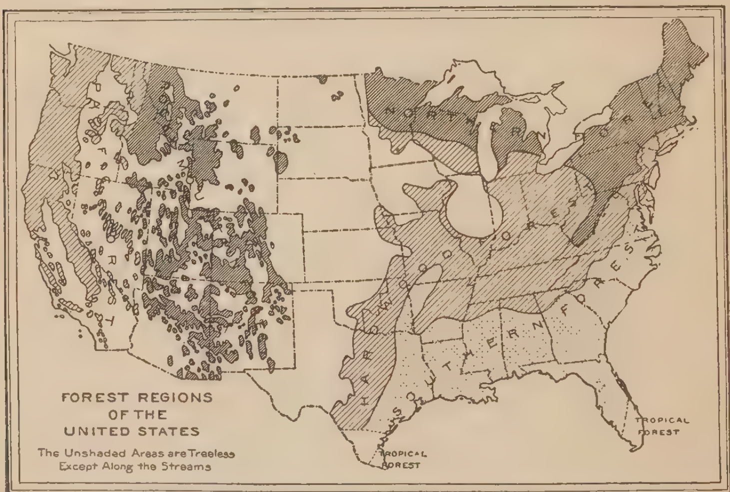


Fig. 271. Map showing forest regions of the United States. Not all the land within the shaded areas had forests, and much has been cleared. The unshaded areas have few forest trees. (U. S. Forest Service.)

posts, poles, cross-ties, ships, railroad cars, bridges, sidewalks, etc. Our dependence on the forests for material for many things is less than formerly. Thus, coal is now used extensively as fuel; brick, stone, and cement for buildings; iron and steel for ships, freight cars, bridges, etc.; wire for fences; and cement for sidewalks. Nevertheless, the yearly drain upon the forests has increased rapidly. The United States is the leading wood-producing country, and it is estimated that its total annual consumption (including that de-

stroyed by forest fires) may amount to 100,000,000,000 or more board-feet.[1] The total value of the forest products in 1909 is estimated at about $1,250,000,000.

Forest regions of the United States. Forests still cover about ¼ the area of the United States. Although the present forest land is more than 3/5 the original area, the amount of good timber remaining probably is not more than half the original amount. This is very significant in view of the comparatively short time the forests of the country have been supplying timber. Fig. 271 shows the five great forest regions of the country.

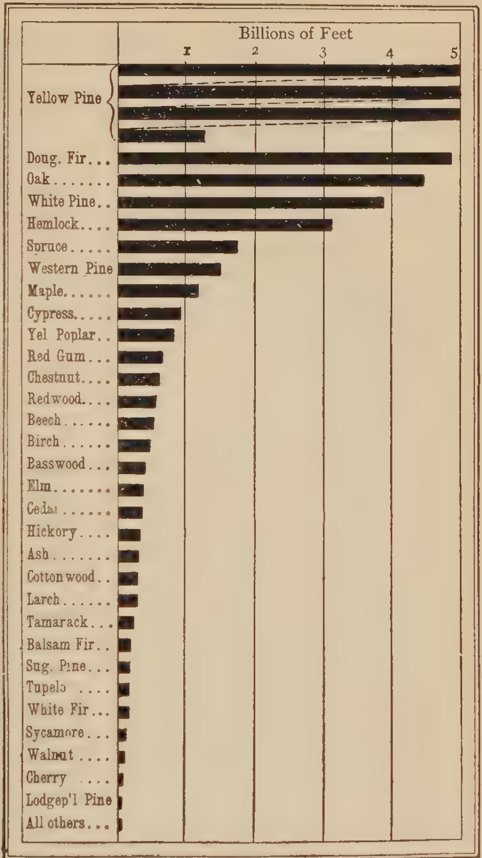


Fig. 272. Diagram showing lumber cut for 1909, by kinds of wood. (U. S. Forest Service.)

(1) The Northern Forest contains both soft and hard woods, though the former have been most important. The leading kinds of trees include white pine, red pine, spruce, hemlock, cedar, balsam-fir, birch, cherry, and sugar maple. (2) The Hardwood Forest contains oak, elm, hickory, cottonwood, maple, basswood, chestnut, ash, etc., not all of which are hard. Cottonwood and basswood, for example, are soft. (3) In the Southern Forest the yellow pine predominates, but in places suited to their growth are cypress, oak, gum, magnolia, and other hardwoods. (4) The Rocky Mountain Forest is almost entirely coniferous; leading trees are the western yellow pine, lodge-pole pine, Douglas fir, larch, spruce, and western red cedar. (5) The Pacific Forest is also

[1] A board-foot is a piece of wood one foot square and one inch thick.

coniferous, consisting chiefly of Douglas fir, western yellow pine, redwood, western red cedar, sugar pine, etc. Fig. 272 shows the lumber production for 1909, by kinds of wood. The cut of yellow pine equaled that of the four next most important kinds; white pine, long in the lead, ranked fourth. These facts reflect the recent rapid growth of lumbering in the southern and western states, and its gradual decline in the Lake states.

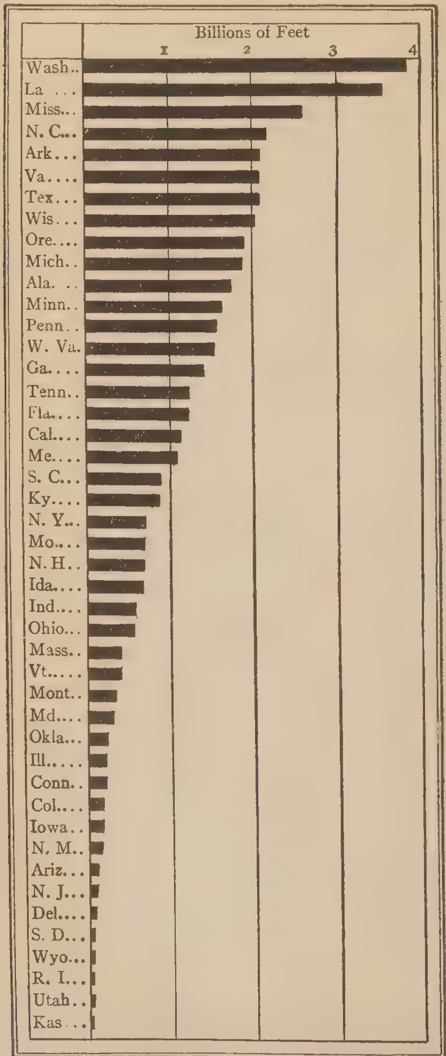


Fig. 273. Diagram showing lumber production by states in 1909. (U. S. Forest Service.)

Distribution of the lumbering industry. As would be expected from the distribution of the forests, lumbering is carried on in every state, but, as Fig. 273 shows, the production varies greatly. For many years the northeastern states, especially Maine and New York, led in lumbering. Since 1850, the industry has declined greatly in that region. The forests of the Great Lakes region were the next to be used extensively (p. 283), furnishing in 1880 about ⅓ the lumber cut of the country. Michigan and Wisconsin became, each in turn, the leading lumbering state; now they rank tenth and eighth, respectively (Fig. 273). At present, the southern states contribute most to the lumber output (Fig. 273); but the industry is expected to reach its climax there within a few

years, and already the Pacific states are large producers. Indeed, Washington is now the leader.

Conservation of forest resources. About 260 cubic feet of wood per capita per year are consumed in the United States. This is greater than the rate of consumption in any other country, about ten times that in France, and seven times that in Germany. Stated in another way, we are taking, on the average, 40 cubic feet of wood per acre per year from our forests. Since the average growth in the forests of the United States is not at present more than 12 cubic feet per acre per year, we are consuming wood more than three times as fast as it is grown in our forests. The United States cannot in the long future count on foreign sources of supply for ordinary structural timber, for other countries probably will need all they can grow. Therefore, if there is to be a permanent supply of wood in this country, we cannot long continue to use more than our forests produce. Clearly, every means of reducing the drain upon the forests, and every means of increasing their production, should be encouraged.

Altogether apart from a supply of timber, the preservation of forests in many places is desirable (1) to reduce soil erosion and the resultant deposition of waste on lower lands, in stream channels, and in harbors (p. 167); (2) to make floods less frequent and less dangerous (p. 237); and (3) to help equalize the flow of streams important for navigation, power (p. 290), or irrigation (p. 298).

The principal ways in which the forest resources of the United States should be conserved may be indicated briefly. (1) Losses from fires should be reduced (Fig. 274). The *average* annual loss of *merchantable* timber is estimated at about \$50,000,000. In addition, many lives have been lost in some forest fires, and villages have been consumed. (b) Great loss is involved in the damage to young trees and seedlings. (c) After high-class timber is burned off an area, the latter may be occupied by inferior kinds of timber. (d) The humus in the soil may be consumed, reducing or destroying the fertility of the latter. (e) Erosion may increase on burned-over areas, and the flow of streams may become more uneven. Forest fires are started by sparks from locomotives, by careless campers and hunters, by careless clearing and brush burning, by lightning, and in other ways. Save those due to lightning, nearly all may be prevented. So far as its funds permit, the Forest Service maintains a patrol in the National Forests, partly with a view to detecting fires at their beginning, and fighting them while they are still small. Some state and private forests also are patrolled during the dry season.

(2) Waste in logging should be reduced so far as practicable. At present it averages about 25% in the timber holdings of individuals and companies, and something less than 10% in the National Forests. In connection with logging

operations, young trees should be protected, and seed trees should be left. (3) The wastes in sawmills and wood-using industries should be reduced. (4) Refuse wood may be used in making many things now manufactured from good timber. (5) Wherever practicable, forest areas should be kept fully stocked with rapid-growing and valuable species of trees. In this way the production of wood in existing forests may be increased greatly. (6) In many places, cut-over or burnt-over areas should be reforested. (7) Posts, poles, cross-ties, mine timbers, pilings,

Fig. 274. Effects of hurricane and fire in a heavy stand of white pine on the Little Fork of St. Joe River, Cœur d'Alene National Forest, Idaho. (U. S. Forest Service.)

shingles, etc., may be treated with some preservative substance, such as creosote, and thus rendered less subject to decay and to the attack of insects. Wood treated in this way lasts 10 to 18 or more years longer than wood not so treated. The general adoption of the practice of treating with preservatives wood used in the above ways would not only lessen the drain on the forests, but also give value to much inferior timber. (8) The enormous waste of forest resources caused by insects can be reduced greatly. (9) The wasteful methods generally followed in the turpentine industry (p. 380) should be abandoned. (10) For many purposes, other material may be substituted advantageously for wood (p. 176). (11) Recently much has been done to conquer the diseases of forest trees, and much more may be done in the future. (12) Standing timber is taxed in most states each year,

and this leads owners in many cases to cut all their timber and put it on the market as soon as possible. Before the principles of scientific forestry can be adopted generally, these tax laws must be reformed.

The Fishing Industries

Nature and general distribution. Fishing on a commercial scale is carried on from many places on the coasts of the United States, and on many inland streams and lakes. The total annual value of the products of the fisheries has exceeded $60,000,000 in recent years, the products of the coast and ocean fisheries making nearly ¾ of the total. The products include not only food-fishes, but the commercial products derived from all other marine and fresh-water animals. About ²/₅ of the products are furnished by animals other than fishes, such as clams, oysters, lobsters, shrimps, sponges, whales, and fur-seals. The leading fish of commercial importance are salmon, cod, shad, menhaden, mackerel, squeteague (or sea trout), haddock, herring, and trout.

Most marine fishing industries are favored by (1) extensive areas of shallow water off shore, to serve as feeding and breeding grounds for large numbers of fish; (2) convenient harbors affording safe havens for fishing boats; and, where the industry is dependent on the sale of fresh fish, (3) nearness to large centers of population. With present facilities for transportation and refrigeration, the last point is less important than formerly.

Where poor soil, rugged surface, or rigorous climate has made farming in coastal regions unprofitable, the people have turned to the ocean for a living. They become fishermen, develop into expert sailors and navigators, and supply men for the great merchant fleets of the world.

Atlantic coast fisheries. Since early colonial days, the fishing industries of the Atlantic coast have centered in New England, which had all the advantages mentioned above. Cod, haddock, mackerel, and herring are taken in largest quantities.

Most of the early settlements along the eastern coast of New England had fishing fleets, and many of them depended almost entirely on the industry. For many years, cod was the leading export of New England. The better fish were taken to southern Europe, while those of poorer quality were sold in great quantities in the West Indies to feed the slaves. Here salted cod was cheaper and more wholesome than meat, and would keep much longer. In early days many fishing towns were scattered along the New England coast at points where the advantages of harbors and nearness to good fishing grounds were combined, and the industry

was carried on chiefly from small boats near land. As the supply of fish near at hand was reduced, larger vessels were built for use on the distant banks, and the industry centered in a few places having special advantages. Gloucester has the best harbor on Cape Ann, and was the first fishing port of the district to secure railroad connection with Boston. Accordingly, the industry developed rapidly there, while it declined at less favored neighboring towns. To-day, Gloucester and Boston are the most important fishing ports in the United States.

The whaling industry was important in New England for many years, although insignificant now. Several things caused its rapid decline during the third quarter of the last century, especially (1) the growing scarcity of whales and (2) the discovery of petroleum in Pennsylvania.

The oyster is the most important shell-fish. It thrives best in relatively warm waters, and in quiet, shallow estuaries and bays, such as those between Long Island Sound and Chesapeake Bay. Some 4/5 of the oysters marketed in the United States come from this part of the coast. At first the industry depended entirely on natural beds of oysters; but as the natural supply declined, the practice grew up of "planting" young oysters, and leaving them to mature.

Pacific coast fisheries. The salmon fisheries are the most important ones on the Pacific coast, but cod and halibut are caught in large numbers. The salmon industry is centered in Alaska, about the shores of Puget Sound, and on the Columbia River. Most of the fish are caught in traps and weirs during the spring or summer run, when they ascend the rivers to spawn. At such times, the waters sometimes have been so congested with salmon that the near-by canneries, working night and day, have found it difficult to handle the fish brought in. Canned salmon is the largest fish export of the United States.

In Alaska, the salmon fisheries rank next to gold mining in value of output. The total value of their product since 1868 is said to be more than $130,000,000, or more than eighteen times the amount the United States paid for Alaska in 1867.

The largest fur-seal herd in the world uses the cool, moist Pribilof Islands (Bering Sea) as a breeding ground, but the estimated number of animals in it was reduced from some 5,000,000 in 1867 to about 200,000 in 1905. In recent years steps have been taken to prevent the extermination of the herd, and to put the fur-sealing industry on a permanent basis.

Mining, Quarrying, etc.

The principal mineral resources of the United States, together with their uses and economic significance, were noted in Chapter XIII. The mining and quarrying of these resources afford employment to

hundreds of thousands of people, and furnish raw material or fuel for many other industries. The total value of the mineral products of the United States in 1910 was about $2,003,000,000. The accompanying table shows the production of the leading mineral substances in that year.

	Quantity	Value
Pig Iron	27,303,567 long tons	$425,115,235
Copper	1,080,159,509 pounds	137,180,257
Gold	4,657,018 troy ounces	96,269,100
Lead	372,227 short tons	32,755,976
Silver	51,137,900 troy ounces	30,854,500
Zinc	252,479 short tons	27,267,732
Aluminum	47,734,000 pounds	8,955,700
Bituminous coal	417,111,142 short tons	469,281,719
Pennsylvania anthracite	75,433,246 long tons	160,275,302
Natural gas	....	70,756,158
Petroleum	209,556,048 barrels	127,896,328
Clay products	....	170,115,974
Cement	77,785,141 barrels	68,752,092
Stone	....	76,520,584
Other structural materials	....	40,821,793
Gypsum	2,379,057 short tons	6,523,029
Phosphate rock	2,654,988 long tons	10,917,000
Salt	30,305,656 barrels	7,900,344
Mineral waters	62,030,125 gallons	6,357,590

Distribution of mineral industries. In general, the distribution of mineral deposits (pp. 175–183) controls that of mining and quarrying, but whether or not a given mineral deposit can be worked profitably depends on several things. Chief among these are (1) its size, (2) its quality, (3) its location, (4) the cost of working it, and (5) market conditions. The relative importance of these factors varies greatly with different minerals.

(1) In many places minerals of value occur in quantities too small to mine. The opening and equipment of a modern mine might be justified by a small deposit of a valuable mineral, like gold or silver, but might not be warranted by a vastly larger deposit of a cheap mineral, like iron. (2) There is much low-grade ore and coal that cannot be mined profitably in competition with better material of the same kind. For example, the United States is estimated to have more than 75 billion long tons of low-grade iron ore, not available (i. e., not workable with profit) under existing conditions, as against less than 5 billion tons which are available. (3) The importance of location

is greatest in the case of minerals which are abundant and cheap, and least in the case of those of great value. Thus iron ore which could be mined with a small profit if near the shores of the Great Lakes, probably could not be mined if in Utah. On the other hand, gold offers great value in small bulk, and so can be transported easily. In recent years, therefore, it has attracted thousands of men to remote sections of Alaska, where most other minerals could not be mined with profit. The discovery of gold in California in 1848 brought nearly 50,000 miners there in 1849, added a new state to the Union in 1850, and gave it a population of 360,000 in 1860. (4) Relatively cheap minerals are mined only where they occur in favorable positions, rather near the surface; those of greater value justify deeper mines and greater expense. In classifying coal lands, the United States Geological Survey has taken a depth of 3,000 feet as the present limit for coal mining. Some of the copper mines of the Lake Superior region are more than a mile deep. (5) The output of many mines and quarries is affected greatly by the demand for the product. The total value of the mineral products of the country declined from $2,071,000,000 in 1907 to $1,595,000,000 in 1908, largely as a result of the business depression which began late in 1907.

The influence of mining on the distribution of population and the growth of cities is discussed elsewhere (pp. 315, 330, 397, 403).

Manufacturing Industries

Growth of manufacturing industries. For many years, most manufacturing in the United States was done in homes. The clothing, utensils, and implements used by the people were largely "homemade," as is still the case in certain regions (p. 309). There were some factories even in the colonial period, and manufactured goods were imported from other countries, especially for the wealthier people. By 1820 or 1825, the factory system was established throughout much of the country then settled. Since 1850, and especially since 1880, the manufacturing industries of the United States have grown with great and increasing rapidity (Fig. 275), until now it ranks first among manufacturing countries. The total value of manufactured products for the country amounted, in 1910, to more than $20,000,000,000. The industrial growth of the last half-century has been due to (1) the increase of population; (2) the improved financial condition and higher standard of living of the people; (3) the increasing supplies of raw

materials; (4) the improvement of transportation facilities; and (5) the growing demand abroad for American goods.

The Location of Industries

Many manufacturing centers specialize in a few products. Thus Brockton, Massachusetts, is the leading boot and shoe center; Grand Rapids, Michigan, is famous for its furniture; and Peoria, Illinois, leads in distilling liquors. In some cases, as in those cited, the reasons for the development of special industries in certain places are clear; in others, the causes are obscure. In general, the most

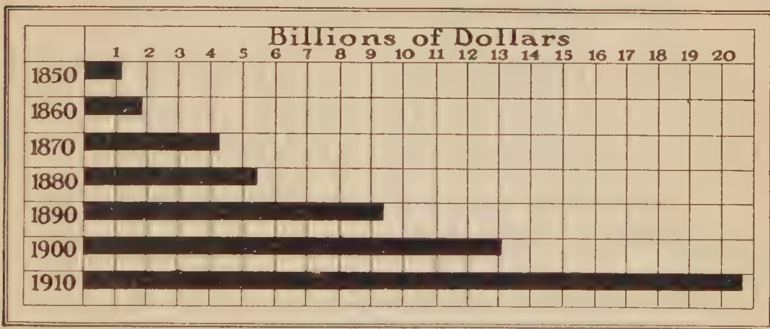


Fig. 275. Diagram showing total value of manufactured products in the United States for the census years 1850–1910.

important factors influencing the location of manufacturing industries are (1) distribution of raw material, (2) command of power, (3) accessibility of market, and (4) a supply of labor.

Distribution of raw material. The influence of the distribution of raw materials in locating the industries which use them is greatest in the case of (1) perishable raw materials, and (2) raw materials that are too bulky and too cheap to be carried far to factories. (1) If prepared and handled carefully, fresh fruits and vegetables may be sent long distances in refrigerator cars (p. 365). But it is impracticable to do this with the large quantities used in the canning, preserving, and allied industries. Hence these industries are located, for the most part, near the places of production. Thus, canning and drying fruit and making wine are important industries in California. Indeed, California furnishes about 9/10 of the dried fruit and some 2/3 of the wine made in the United States. In

New Jersey and Delaware ¾ of the total canned product are tomatoes. Similar influences appear in the case of many animal products. The centering of slaughtering and meat-packing in Chicago, South Omaha, and Kansas City is due partly to the losses which result from shipping live animals long distances. Butter, cheese, and condensed milk are manufactured extensively where large quantities of milk are produced, as in New York, Wisconsin, and Iowa.

(2) Among the raw materials that are too bulky or too cheap to be carried economically to distant points are many of the products of the quarries, mines, and forests. Hence the industries which use these materials are located in most cases near the sources of supply. In some cases, on the other hand, special conditions make it practicable to take bulky raw material to remote manufacturing plants. Thus granite from Massachusetts or marble from Vermont is shipped profitably for monumental purposes throughout the country, because when cut and polished in a local yard a single piece may have a market value of hundreds of dollars. Again, it may be feasible to take bulky raw material to distant points because of very cheap transportation, as in the case of the iron ore of the Lake Superior region (pp. 268, 282).

The tendency of wood-working industries to keep close to the lumbering districts is indicated by the distribution of saw-mills, wood-pulp mills, the turpentine industry, charcoal burning, and, less strikingly, furniture making. The wood-pulp industry was most important originally in western Massachusetts, and later in Pennsylvania, but as the supply of pulp-wood decreased, the industry became more important elsewhere. It is now centered in Maine, northeastern New York, and Wisconsin, where spruce and hemlock, the principal woods used in the industry, are more abundant. These regions have the additional advantages of abundant water power and relatively near markets for the finished products. The manufacture of furniture was carried on chiefly in the East until some twenty years ago, with New York the leading center. Now Chicago stands well ahead of New York, and Grand Rapids is a close third (p. 288). This migration of the industry followed the shifting of the center of lumbering from the northeastern states to the Great Lakes region (p. 372). Recently, the growth of lumbering in the Gulf states and northwestern states (p. 372) has led to a rapid development of furniture-making in those sections. The manufacture of tar, pitch, and turpentine has long been an important industry in the South. These things are made chiefly from the "sap" of the long-leaf pine, and this is obtained, in most cases, by frequently making needlessly large cuts in the lower part of the trunk. The average period during which a given tree furnishes sap under this method is only four years, and this has caused a steady migration of the center of the turpentine industry. North Carolina led for a time, then South Carolina came to the front. From South Carolina the industry spread into Georgia, where it is beginning to decline. Now Florida leads, and the industry is spreading rapidly into Alabama and Mississippi. The Forest Service has developed new methods of obtaining the sap from smaller cuts. The

general adoption of these methods will increase greatly the life of the industry.

Most ores, except iron, have relatively high values for small bulk, but as they come from the mine, they are likely to be associated with much worthless material. Hence the metallic matter in most cases is partly separated from the waste (i.e., is *concentrated*) at the mine. It may also be smelted (metal extracted from the ore) at the mine, but since in its concentrated form it is commonly valuable enough to bear rather heavy freight charges, it is shipped in many cases to some big smelter, where large-scale operation reduces the cost. Refining the metal may be done in turn far from the smelter. Thus, silver ore mined in Leadville, Colorado, may be concentrated at or near the mine, smelted in Pueblo, refined in Jersey City, and manufactured into jewelry in Providence, Rhode Island.

The source of many raw materials of high value has little if any influence on the location of the industries which use them. This is determined by other factors.

Many illustrations might be given. The United States produces no raw silk for the many silk mills of New York, New Jersey, and Pennsylvania. Lowell, Massachusetts, manufactures large quantities of woolen goods, although New England now raises few sheep (p. 368).

Influence of power resources. Available power may be the leading factor determining the location of manufacturing plants which use raw material suited to economical transportation. Water power determined the location of many of the older manufacturing centers of New England (p. 288). Some of these places had small power resources, and depended on the local supply of raw material; such places have declined. Others have continued to grow because they had larger power resources and were so situated that, as transportation facilities were improved, they could use raw materials from increasingly distant points, and could bring in coal to supplement their water power. There are said to be more than forty important manufacturing cities in southern New England that can trace their start to an early advantage in water power. Nearly all of them now use much more steam power than water power.

The use of coal and steam power in manufacturing increased rapidly after 1850. The growth of railroads steadily increased the number of places which could get coal, and also made cheaper the movement of raw materials to places situated favorably with respect to supplies of coal. The advantage of large deposits of good coal has had much to do with the remarkable industrial development since 1850 in the region extending from western Pennsylvania to Illinois.

The use of other mineral fuels for industrial purposes also has located certain manufactures. Thus the discovery of natural gas in western Pennsylvania, Ohio, Indiana, and West Virginia attracted many industries because of the cheap and

excellent fuel offered. In many places the supply of natural gas failed after a few years, and as a result many factories were abandoned or moved; some of the larger ones continued to operate by bringing in coal. California is beginning to feel the benefit of the large supplies of cheap oil discovered there within the last few years. Formerly, the industrial development of the state was retarded by the fact that much fuel had to be imported at relatively heavy expense.

As the supply of fuels diminishes, hydro-electric power will be used more and more in manufacturing (p. 289). But the ease of transmitting the power to considerable distances removes the need of locating the factory near the source of the water power (p. 288).

Influence of nearness to market. The advantages of a nearby market, or of superior facilities for shipping goods to more distant markets, have been leading factors in determining the location of many industries.

An example is afforded by the location of the leading refineries handling imported cane-sugar. Sugar is refined and molasses is manufactured to some extent in Louisiana, where cane is grown. But much cane-sugar is imported, and the largest refineries are in New York and Philadelphia, in part because of the heavy local consumption and the excellent means of distribution to outside markets. Furthermore, by having the refineries at tidewater the cost of transporting the raw material is reduced.

A more striking case is that of the manufacture of agricultural implements. The chief market for these things is in the leading farming sections. Many implements are very heavy and occupy much car-space, so that freight rates on them are high. For their manufacture, there is accordingly great advantage in a location near the chief market. As a result, there has been a steady westward migration of the industry as the great grain districts have expanded in that direction (p. 361). In 1880, Ohio and New York were leaders in the industry; now, Illinois is far ahead of both combined, its output having increased threefold between 1880 and 1910.

Influence of supply of labor. The importance of a local supply of labor in determining the location of manufactures varies greatly. It depends in part on the character of the industry, being more important in the case of industries requiring skilled labor than in others. In general, it is much less important now than formerly, for it has become increasingly easy to attract laborers to any given point where other conditions are favorable. Doubtless, too, labor will be even more mobile in the future.

In the past, manufacturing in parts of the South and in California has been retarded by lack of a satisfactory supply of labor. On the other hand, the leadership of New York City in the ready-made clothing industry is due in part to the presence of abundant cheap labor. The supremacy of New England in the manufacture of cotton has been maintained of late years largely through the possession of expert workers.

Other factors. In addition to the leading factors discussed above, there are various minor factors which may influence the location of manufacturing industries. Thus the advantage of an early start has located certain industries in places without superior natural advantages. In most cases this advantage is associated closely with the question of labor.

The boot and shoe industry of Brockton, Lynn, and Haverhill, Massachusetts, illustrates the advantage of an early start. The industry was established in these places at an early date, and by enlisting the services of many of the people, a supply of skilled labor was developed with enough impetus to give first rank to the localities. Most of the shoe factories of these cities are run by steam power, developed from Pennsylvania coal, and most of the leather they use is tanned in other states. Clearly, their leadership rests on an insecure basis, and the business is growing fast in other cities having more fundamental advantages.

In earlier years, industries frequently were established in particular places because of a supply of local capital, but now such cases are relatively few and unimportant. Broadly speaking, capital is perfectly mobile, and goes wherever other conditions are favorable. Climate may also be a direct factor in determining the location of manufacturing industries, though its influence is offset easily by other considerations. Thus the climate of the northern states is more invigorating than that of the southern states, and workingmen are likely to render more efficient service, on the average, in the former than in the latter. Yet because of other advantages, the manufacturing industries of the South are growing rapidly.

Combined influence of various factors. While many industries are located largely or wholly by one or two factors, the distribution of others is the result of the combined influence of most or all of the things mentioned above. Many industries, too, have been located without regard to the geographic and economic conditions involved, and not a few have failed for this reason.

Further illustrations of the leading factors which influence the distribution of industries occur in the following pages, in connection with the discussion of the leading manufactures of the country.

The leading manufacturing states and cities. New York, Pennsylvania, Illinois, Massachusetts, and Ohio, in this order, are the five leading manufacturing states, while New York, Chicago, Philadelphia, St. Louis, and Cleveland are the five most important manufacturing cities. In 1910, the combined value of the manufactured products of cities having a population of 10,000 or more was more than twice that of smaller cities and rural districts. The more rapid growth of urban as compared with rural population has been one of the most striking and significant things in connection with the population changes of recent years (p. 399). It has been due in large part

to the rapid growth of urban industries. The factories in the territory east of the Mississippi River and north of the Ohio and Potomac rivers employ about ¾ of all the industrial wage-earners (not workers on farms) of the country, and contribute about the same proportion of the total value of manufactured products.

Leading Manufactures of the United States

The Federal Census Bureau has divided the 339 classes of manufactures that are carried on in the United States into 14 groups. These are shown in the accompanying table.

MANUFACTURING INDUSTRIES OF THE UNITED STATES
(*Ranked according to value of product in 1909*)

Group	Year	Number of establishments	Wage earners (average number)	Value of products
Food and kindred products	1909	55,364	411,575	$3,937,617,891
	1899	41,247	301,868	2,199,203,442
Iron and steel and their products	1909	17,289	1,025,044	3,163,126,293
	1899	14,080	744,069	1,818,036,771
Textiles	1909	21,695	1,437,258	3,054,708,084
	1899	17,640	1,021,869	1,627,889,077
Lumber and its manufactures	1909	48,533	907,514	1,582,522,263
	1899	34,947	669,043	1,004,716,682
Chemicals and allied products	1909	11,745	237,988	1,430,901,954
	1899	8,687	179,539	726,105,558
Metals and metal products, other than iron and steel	1909	8,750	248,785	1,238,251,401
	1899	4,996	160,422	688,927,152
Paper and printing	1909	34,828	415,990	1,179,285,247
	1899	26,627	298,744	607,957,231
Vehicles for land transportation	1909	8,248	507,311	999,326,577
	1899	8,738	314,283	504,969,835
Leather and its finished products	1909	5,728	309,766	992,713,322
	1899	5,625	248,626	582,047,900
Liquors and beverages	1909	7,347	77,827	674,311,051
	1899	5,740	55,120	382,898,381
Clay, glass, and stone products	1909	16,168	342,827	531,736,831
	1899	11,524	231,716	270,650,143
Tobacco manufactures	1909	15,822	166,810	416,695,104
	1899	14,959	132,526	263,713,173
Shipbuilding	1909	1,353	40,506	73,360,315
	1899	1,107	46,747	74,532,277
Miscellaneous industries	1909	15,621	485,845	1,397,495,537
	1899	11,597	308,191	655,279,079
United States	1909	268,491	6,615,046	20,672,051,870
	1899	207,514	4,712,763	11,406,926,701

Food and kindred products. The more important items in this group are slaughtering and meat-packing products; flour and grist mill products; butter, cheese, and condensed milk; canned and preserved fruits, vegetables, and fish; and refined sugar (p. 382).

The slaughtering and meat-packing industry tends to keep close to the great stock-raising areas (pp. 366–368), in order to avoid freight charges on waste material and to prevent the animals losing weight on the way to the slaughtering centers. The total value of the products of the industry in 1910 was $1,370,000,000.

Grazing naturally precedes farming in the order of economic development (Why?), and as the chief grazing area moved westward in front of the advancing agricultural zone, the slaughtering and packing industry followed. In early days, stock was driven from the pastures of the Piedmont Plateau to be killed at Philadelphia, Baltimore, and Charleston. The battle of Cowpens, in the Revolutionary War, was so called because fought about the pens of a Piedmont cattle ranch. Later, great numbers of cattle and hogs were driven to the seaboard from the settlements west of the Appalachians (p. 274). After the War of 1812, the pork-packing industry found its chief center in Cincinnati, where it remained until about 1860 (p. 276). During this period, the business was carried on also at various other points on the Ohio canals and the Ohio, Mississippi, Illinois, Wabash, and other rivers. By 1861–1862, the center of the industry had moved from Cincinnati to Chicago, and the business had declined in many of the river towns. Greater economy in manufacture was possible in a small number of large establishments than in a large number of small ones, and Chicago, as the greatest railroad center, had unrivaled facilities for assembling the stock. It is also on the northern edge of the corn belt (Fig. 259; Why important?), and within easy reach of the great grazing lands. Chicago still leads in the industry, contributing nearly ⅓ of the total value of the products for the country, but the second and third centers are found on the Missouri River, at Kansas City and South Omaha, respectively. The most important thing in the recent history of this industry has been the more and more nearly complete use of the waste products of the slaughter houses. Among the things made from these products are soap, candles, glue, gelatine, glycerine, ammonia, knife-handles, and fertilizer.

The value of the flour and grist mill products of the United States has increased rapidly with the growth in the production of cereals, and in 1910 amounted to more than $880,000,000. Five-eighths of the value of the output of these mills is in wheat flour. Other important products are rye and buckwheat flour, corn meal, and feed for animals. All branches of the industry have expanded westward, following the westward movement of the centers of production of the great cereal crops (Fig. 261). Flour and grist mills are distributed widely, for with the exception of a comparatively few large mills, they supply local demands only. Minnesota, New York, Kansas,

Ohio, and Illinois are the leading flour-producing states, and Minneapolis is the leading city (p. 288).

The manufacture of dairy products in factories is a modern development. Formerly, this work was done almost entirely on the farms. In 1851, there was only one cheese factory in the United States; in 1905, there were more than 3,600. New York, Wisconsin, Iowa, Illinois, Minnesota, and Pennsylvania are the six leading states in the industry (p. 366). The value of factory-made butter, cheese, and condensed milk exceeded $270,000,000 in 1910.

The canning and preserving of foods is a comparatively new industry in the United States, having little importance before 1850. Now, the total yearly value of canned foods, exclusive of meats, is about $160,000,000. The leading states in the industry are California, Maryland, and New York. The conditions which determine the distribution of the industry have been given (p. 379).

Iron and steel and their products. This group of manufactures ranks second in value of product (p. 384). It comprises 37 industries, the basic ones being the manufacture of iron and steel. Among the others are those producing structural iron work, rails, machinery, tools, hardware, tin plate (really sheets of iron coated with tin), and various small products. The iron and steel industry is carried on in some 27 states, but nearly 9/10 of the total output comes from Pennsylvania, Ohio, Illinois, and Alabama.

The successful use of hard coal as fuel gave the first great impulse to iron production, and located the iron industry in eastern Pennsylvania, with Philadelphia the leading market. About the close of the Civil War, the center of the industry moved to Pittsburgh, where it still remains. A number of influences led to the change: (1) The hard coal of eastern Pennsylvania, because less abundant and in great demand for domestic use, cost more than the soft coal of the western part of the state. Furthermore, coke made from the latter was more efficient, ton for ton, than hard coal. (2) The Lake Superior ore was of high average grade, was mined easily, and could be brought to Lake Erie ports cheaply by lake. (3) The rapid development of the country west of the Appalachians helped to bring about the change. Although Pittsburgh did not become the center of the industry until after the Civil War, it had nail factories, foundries, and the like, before the beginning of the century. As indicated elsewhere (p. 282; Fig. 198), Lake Superior iron ore goes to Pennsylvania coal, rather than the reverse, because much more coal than ore is needed in the manufacture of steel, and because the ore, in being sent to Pittsburgh, is on the way to its final market. Various phases of the iron industry are carried on less extensively at other cities on or near the Great Lakes, especially at Chicago and Cleveland, where ore and coal can be brought together cheaply, and where market conditions are good.

In the South, Birmingham, Alabama, is the leading center of the iron and

steel industry. In smelting iron ore it is mixed with limestone and coke, and when the mixture is heated in the furnace, the metal iron is released from the ore, and is drawn out into molds. At Birmingham, iron ore, coal, and limestone are found close together. This fortunate combination (with the Southern market) has made Birmingham an important city, and a leading factor in the industrial growth of the southern states.

Textile manufactures. The industries of this group furnish the materials for nearly all our clothing and for many household articles, such as rugs and carpets, draperies, and bedding. Vegetable and animal fibers constitute the raw materials used by the 44 textile industries. The principal industries of the group are based on cotton, wool, and silk. Various products are made also from flax, hemp, and jute.

The textile mills of the United States consumed in 1910 about 2,500,000,000 pounds of raw cotton, valued at more than $290,000,000. The value of the cotton manufactures was more than $620,000,000. Southern New England has led in the manufacture of cotton throughout the history of the industry in the United States, but now its leadership is threatened seriously by the South Atlantic states. New England has the advantage of a much earlier start in the industry, and of a better supply of labor (p. 382); but the southern mills are very much nearer the cotton fields. Both sections possess abundant water power. This is a minor factor in New England, but a very important one in the South.

Woolen manufactures include worsted goods, suiting, blankets, carpets, felt goods, and wool hats. Much wool is imported for the mills, which consume more than 500,000 000 pounds annually. The leading manufacturing centers are in the Middle Atlantic and New England states.

The silk mills of the United States are dependent entirely upon foreign countries for raw material. Mulberry trees could be grown and silkworms reared in this country, but the industry requires much hand labor, and the cost of the latter in the United States prevents the production of raw silk as cheaply as it can be produced in southern Europe, Japan, and China. The leading silk-manufacturing states are New Jersey, Pennsylvania, New York, and Connecticut.

Lumber and its manufactures. The logging camp and lumber mill furnish material for the 23 other branches of industry included in this group. The fundamental industries have been discussed (pp. 370–372). Among the products of the industries which use lumber are doors, blinds, sash, interior finish, boxes, matches, "woodenware," and furniture (p. 380). Great quantities of lumber are used also in building, and in certain industries included in other groups, such as shipbuilding and the manufacture of carriages and wagons. Lumber products are manufactured on a commercial scale in every state, in marked contrast with the concentration of certain of the

other greater industries, such as the manufacture of iron and steel and textiles.

Chemicals and allied products. This group contains many manufactures which serve a wide variety of purposes. Among the products are paints and varnishes, dyestuffs, bleaching materials, medicines, druggists' preparations, baking powder, glue, soap, ink, various oils, explosives, and fertilizers. Naturally, such diverse commodities are manufactured in many different places, but more than half the products of the group as a whole come from Pennsylvania, New York, New Jersey, Ohio, and Illinois.

Metals and metal products other than iron and steel. Many things are made of gold, silver, copper, lead, and zinc (pp. 181-182), such as jewelry, watches, clocks, silverware, brassware, and pins. Many of the 34 classes of industry belonging to this group are carried on extensively in the northeastern states, especially southern New England. The chief advantages enjoyed by this section in these industries are (1) an early start, and (2) the services of skilled workers, more numerous there than elsewhere during the early development of these industries.

Paper and printing. Printing and publishing are the most important and most widely distributed industries of this group, which includes also the manufacture of wood-pulp, paper of all kinds, paper bags and boxes, etc.

The principal centers of the wood-pulp industry have been noted (p. 380). The output of paper boxes has increased rapidly during recent years; largely because of the increasing cost of wood, many things are now put up in paper boxes which formerly were packed in wooden boxes. The annual per capita value of the output in the printing and publishing business is more than ten times greater than it was in 1850. This significant change reflects in part the progress made in education, the reduced cost of reading matter, and the greater facilities for its distribution, such as rural free delivery. In 1905, the value of the products of printing and publishing in six states — New York, Illinois, Pennsylvania, Massachusetts, Ohio, and Missouri — amounted to ⅔ that for the entire country.

Vehicles for land transportation. The operations of the repair shops of steam railroad companies, the manufacture of carriages and wagons, and the manufacture of steam railroad cars are the most important of the 11 industries comprising this group. In recent years the output of bicycles has declined rapidly, while that of automobiles and motorcycles has increased enormously.

The value of the automobiles made in 1900 was less than $5,000,000; in 1910, about $165,000,000. In 1905, automobiles were manufactured in 17 states, with

Michigan, Ohio, New York, and Connecticut leading. The value of those made in Detroit is more than ⅓ of the total for the industry. The leadership of Detroit appears to be due to the impetus resulting from the success of the first factories established, rather than to superior natural advantages.

Leather and its finished products. The basic industry in this group is tanning, while the dependent industries include the manufacture of leather products of all kinds. Of the latter, the boot and shoe industry is most important, but large quantities of leather are used in making harnesses, saddles, trunks, bags, furniture, gloves, mittens, and belting, in binding books, and in other ways. For many years Massachusetts has been the leading shoe-manufacturing state (p. 383), but the industry is growing rapidly at various points in the middle states.

In the past, the tanning industry has depended chiefly on local supplies of tannic acid, obtained usually from the bark of oak or hemlock, and as the supply of bark failed in one area, the industry developed in another. The business is now important in Pennsylvania, Michigan, and Wisconsin. Until recently, the industry was attended by an enormous waste of timber; trees were felled by thousands, from which only the bark was taken for the tanneries, the logs being left to rot in the woods.

Liquors and beverages. The value of these products increased more than ⅔ between 1900 and 1910, amounting to more than $590,-060,000 in the latter year. Illinois leads the states in making distilled liquors, while Indiana, Ohio, and Kentucky follow in the order named. New York, Pennsylvania, Wisconsin, Missouri, and Illinois are the leading states in the production of malt liquors. California, New York, and Ohio lead in wine-making.

Peoria, Illinois, ranks first among American cities in the manufacture of distilled liquors. It attained leadership in the liquor industry largely because of (1) its central location in the corn belt of the state; (2) its transportation facilities, which enable it to collect at low freight rates the surplus grain of the surrounding area; and (3) an abundant supply of cheap coal from nearby mines. The manufactured product, owing to its relatively small bulk and large value, can bear the cost of transportation to distant markets. Nearness to the grain supply has also been an important factor in the manufacture of malt liquor in Milwaukee, Chicago, St. Louis, Cincinnati, and St. Paul.

Clay, glass, and stone products. Some of the industries of this group have been noted sufficiently in earlier connections (pp. 175-176, 266). Clay products are used most in the building trades, and their consumption is increasing rapidly. Ohio, Pennsylvania, New Jersey, Illinois, and New York lead in clay products. Pennsylvania, Indiana, and Ohio lead in the manufacture of glass.

Deposits of quartz sand, the only raw material which enters into all kinds of glass, are widespread, but the making of glass on a large scale is fairly well localized because of the need of satisfactory fuel for the work. With good fuel, a skillful glass-maker can make fairly good glass from inferior material, but with poor fuel he cannot make good glass with the best materials. Gas is the ideal fuel in glass-making, because it is cleanest, and gives intense, uniform heat under perfect control. The leading states in the industry attained that position largely because of their supplies of natural gas.

Tobacco products. These include cigars, cigarettes, chewing and smoking tobacco, and snuff. The value of the products increased from $31,000,000 in 1860 to $416, 000,000 in 1910.

The manufacture of cigars is distributed widely, Pennsylvania, New York, and Ohio leading. More than 4/5 of the total output of cigarettes are made in New York and Virginia. Missouri, North Carolina, Kentucky, and Virginia lead in the production of chewing and smoking tobacco.

Shipbuilding. Since 1850, the value of the products of this industry has increased nearly fourfold and the capital invested twenty-one fold. The latter fact means that, as iron and steel steamships replaced wooden sailing vessels, much more capital was required than when ships were built of wood only. The need of greater capital helped to bring about the concentration of shipbuilding in large establishments, with the result that there were only about half as many establishments in 1905 as in 1880. New York, Pennsylvania, Virginia, New Jersey, and Massachusetts are the leading shipbuilding states on the Atlantic coast; Ohio and Michigan lead on the Great Lakes; and California and Washington on the Pacific coast.

The rapid growth in recent years of the shipbuilding industry on the Great Lakes has been due to the demand created by the enormous increase in the commerce of the lakes (pp. 279, 282). At the same time, of course, the development of shipbuilding has favored the continued growth of lake transportation. The shipyards at West Bay City, Michigan, and West Superior, Wisconsin, are outgrowths of the wooden shipbuilding industry. Those at or near Buffalo, Lorain, Cleveland, Toledo, Detroit, and South Chicago are located conveniently with reference to the great steel mills.

Miscellaneous industries. There are 65 industries of varying importance carried on in the United States which cannot be classed properly with any of the other groups. The combined value of their products in 1910 was more than $1,400,000,000. Among the industries of the group whose products are of greater value are the manufacture of agricultural implements (p. 382); ammunition; brooms and brushes; buttons; coke (p. 386); electrical machinery, apparatus,

and supplies; fur goods; ice; mattresses and spring-beds; musical instruments; photographic materials and apparatus; and rubber and elastic goods.

Questions

1. (1) Explain the fact that the shores of Chesapeake Bay, Long Island, and Lake Michigan (east shore) were among the first sections to grow vegetables on a large scale for city markets. (2) Why is the business more important on the *east* shore of Lake Michigan than on the *west* shore?

2. Formerly strawberries were grown extensively in a few places only, as in parts of Maryland, New York, Ohio, and western Michigan. Now they are grown on a large scale in Florida, Tennessee, Arkansas, Missouri, and other states. (1) Explain the relatively early development of the business in the first-mentioned states. (2) What permitted its later development in the other states?

3. It is estimated that the forests of the United States (Fig. 271) contain about the following percentages of their original stand of timber: Northern Forest, 30 per cent; Hardwood Forest, 21 per cent; Southern Forest, 50 per cent; Rocky Mountain Forest, 75 per cent; Pacific Forest, 79 per cent. Why the differences?

4. What advantages have made New Jersey a great manufacturing state (6th in 1910), in spite of the fact that it has small fuel and water-power resources, and produces relatively little of the raw material used by its factories?

5. Explain the fact that in Nebraska most of the manufacturing is done in the eastern part of the state (more than $^4/_5$ of it in two counties), while in Iowa it is distributed rather evenly throughout the state.

6. Among the leading manufactures of Chicago are meat products, men's clothing, foundry and machine shop products, iron and steel, the products of printing and publishing houses, and railroad cars. What advantages has Chicago for carrying on each of these industries?

7. Compare and contrast the general advantages for manufacturing of (1) Massachusetts and Texas, and (2) Utah and Ohio.

8. Flour and sugar are household necessities. (1) Explain why the former is made in thousands of mills throughout the country, and the latter at comparatively few points. (2) Will the situation with regard to sugar change in the future? Why?

9. Why does West Virginia rank low (29th) as a manufacturing state, although it mines much coal (second coal-producing state in 1910)?

10. Explain the fact that the section east of the Mississippi River and north of the Ohio and Potomac rivers contributes about ¾ of the total value of manufactured products for the United States.

CHAPTER XXI

DISTRIBUTION OF POPULATION; DEVELOPMENT OF CITIES

Factors Affecting Density

As we have seen, the distribution and density of population are influenced by many factors — such as topography, climate, soil, natural resources, transportation facilities, and the occupations of the people. The influence of these factors may be reviewed by considering briefly the expansion and present distribution of population in the United States.

Fig. 276 shows the distribution of population in 1790, when the first census was taken. Nearly all the people, emigrants from Europe, were still east of the Appalachian Mountains. This was due largely to the difficulty of crossing the mountain barrier, the privations, dangers, and difficulties of life in the Interior, and the desirability of being near the Atlantic Ocean or some navigable river flowing into it, for purposes of trade. Furthermore, the lands east of the mountains and along the Great Appalachian Valley had been sufficient for the needs of the settlers until a few years before (about 1775).

In New England, the population was densest toward the south and southeast. This is explained by the colder climate at the north; the rough uplands there, infertile in many places; the fact that few of the rivers served as good highways far into the interior (Why?); and the importance of sea-interests (fishing, shipbuilding, the carrying trade) in New England life. The influence of the Connecticut Valley and the Champlain lowland on the distribution of the frontier population is interesting. In New York, most of the people were in or near the Hudson and Mohawk valleys, which had fertile soils in many places, and afforded easy communication with New York City. The Adirondacks and Catskills were almost uninhabited. The sandy, forested coastal plain of southeastern New Jersey had a sparse population, while a strip of denser settlement extended across the state between Philadelphia and New York City. (Why? Compare with Figs. 278 and 281.) In the Carolinas the Piedmont Plateau, with its relatively small farms, had a denser population than parts of the Coastal Plain, with its big plantations. The influence of the Great Appalachian Valley is shown by the settled strip which extended southwest from Virginia. The settled area in southwestern Pennsyl-

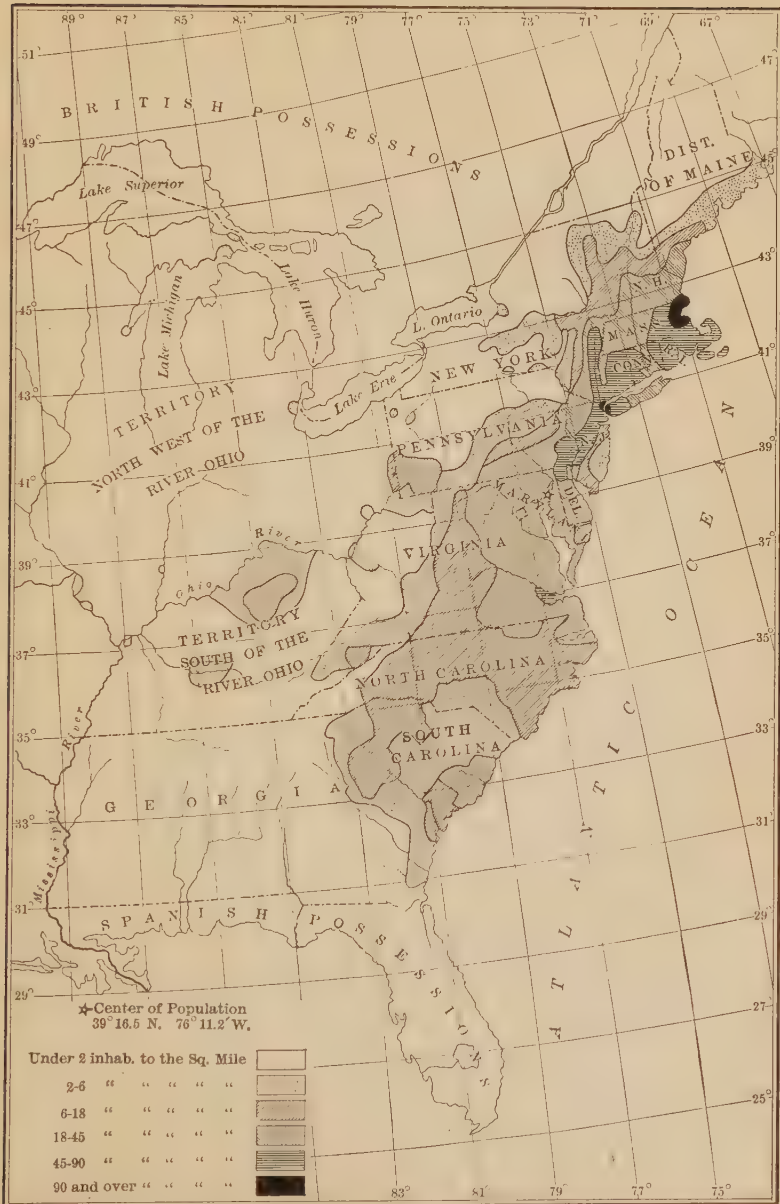


Fig. 276. Map showing distribution of population in the United States in 1790.

vania reflects, in part, the attractions of the Monongahela Valley and some of its tributaries. The large area of settlement in north-central Kentucky was the famous "Blue Grass Region." Here were rich soils, salt springs (p. 183), and navigable streams. The settlers of central Tennessee were also in a region of fertile soils, and used the Cumberland River as a highway. The rough plateau lands of eastern Tennessee, Kentucky, and West Virginia had few settlers, or none at all.

After 1790 population spread rapidly toward the west (Fig. 277), especially along such highways as the Ohio River and (later) the Great Lakes (p. 281). The population map for 1820 (Fig. 278) shows strikingly the influence of geographic features. The Adirondack Mountains and the less accessible parts of the Appalachian Mountains and the Alleghany Plateau remained uninhabited wil-

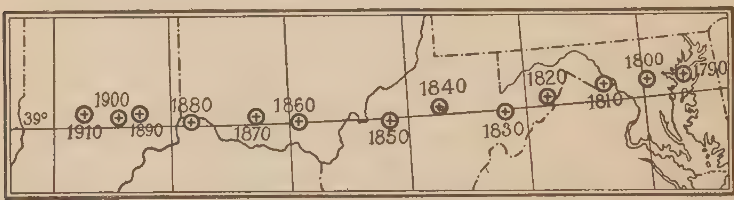


Fig. 277. Map showing the center of population in the United States at each census, 1790 to 1910.

dernesses. On the other hand, most of the fertile lowlands favorably situated and available for settlement had been occupied. The most striking feature of the western frontier was the control of settlement by the larger rivers, which were the chief highways of the time (pp. 274–276). Each one (the Red, Arkansas, Missouri, Mississippi, and others) was bordered for some distance by a narrow settled area, while, for the most part, the tracts between were still unoccupied. The influence of routes from the East is illustrated by the belt of settlement extending from western New York around the southern shore of Lake Erie to Lake St. Clair. The presence of Indians explains some of the blank areas on the map within the generally settled region, as in Georgia, Alabama, central and northern Mississippi, and western Tennessee. After the removal of the Indians, these areas were settled quickly.

The unsettled condition of northwestern Ohio was due partly to the "Great Black Swamp." The lower part of the Mississippi delta and some of the lands along the Gulf coast also were unoccupied because swampy. For some years, settlers avoided the prairies of the northern Interior. They were thought infertile (p. 173); timber must be had for buildings, fences, and fuel; they did not afford

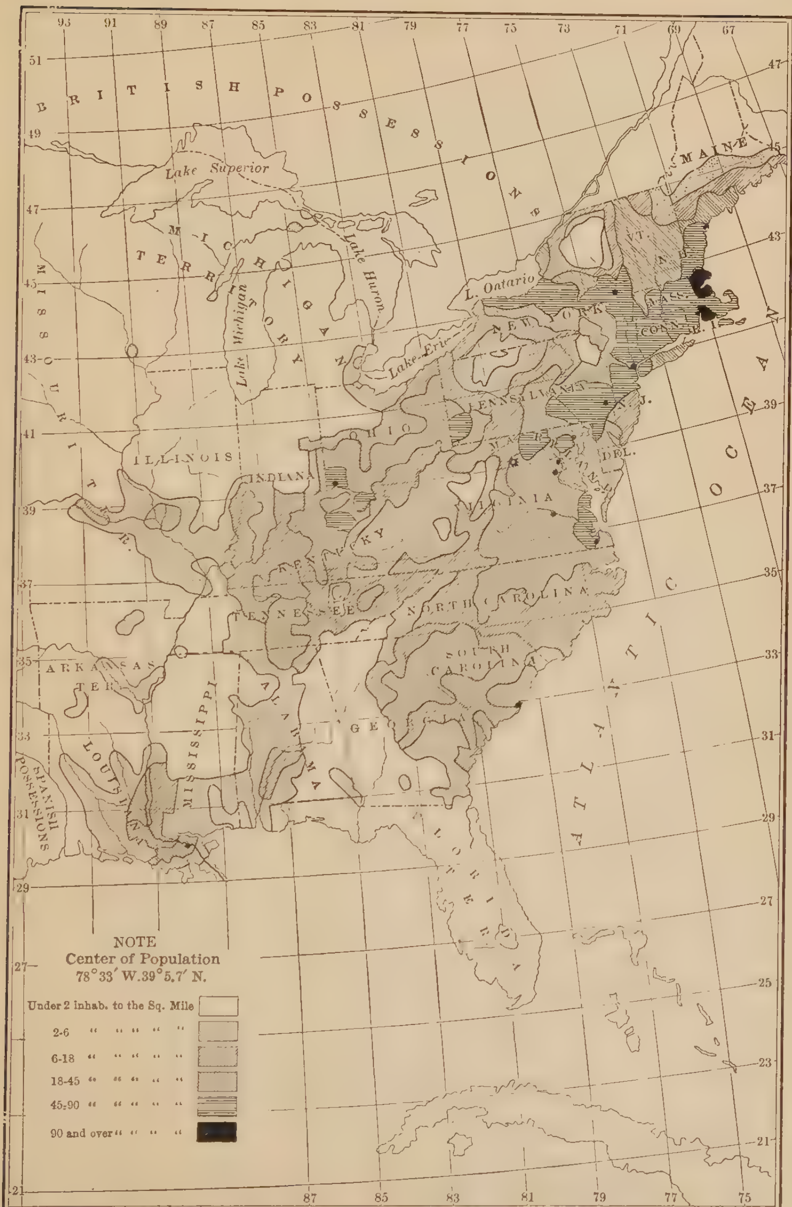


Fig. 278. Map showing distribution of population in the United States in 1820.

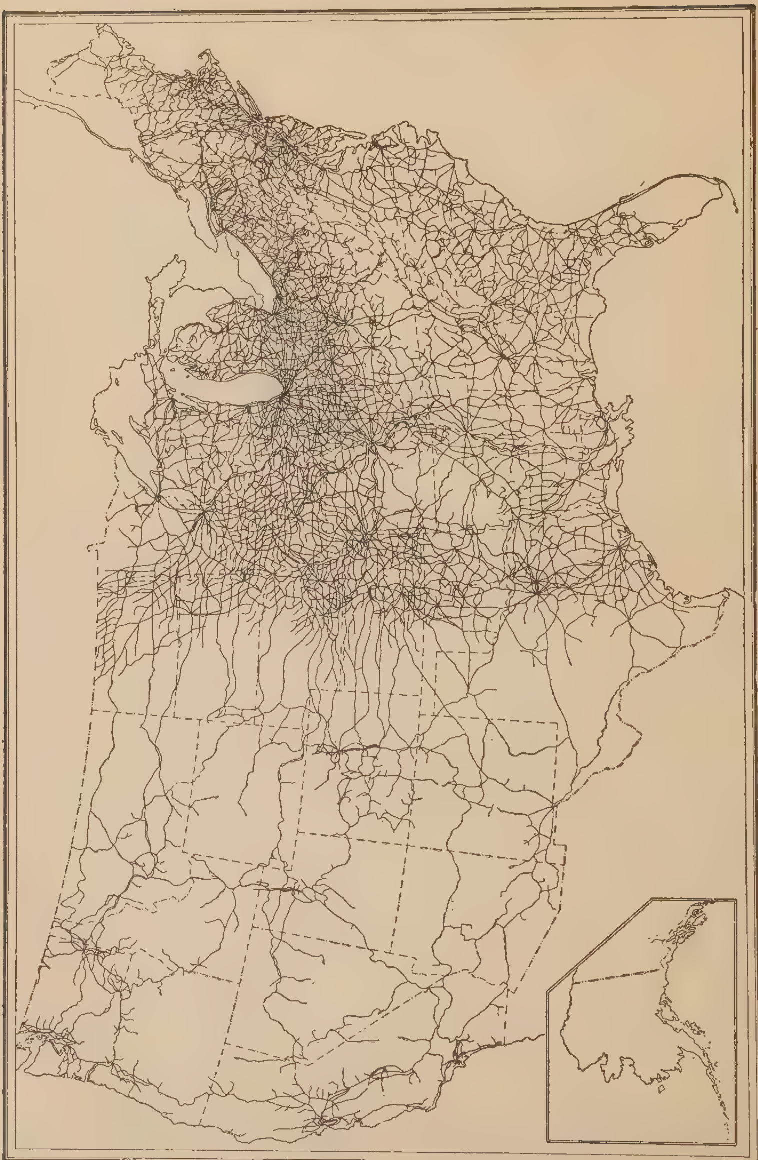


Fig. 279. The railroads of the United States in 1911.

enough running water for stock or mills; there was little protection from the bitter winds of winter; and the farmers did not know how to "break" and work the tough prairie sod. The gradual conquest of the prairies is one of the most interesting phases of the settlement of the region. The dense forests in the northern Lake region helped for years to keep farmers away from large areas.

The appearance of the railroad introduced a new and powerful factor in the expansion of population. The first American railroad was built in Massachusetts in 1826. By the early 1850's, railroads had been built across the Appalachian Mountains from the leading seaports of the Northeast. In 1853 Chicago was connected by rail with New York City. The Mississippi River was reached shortly after, and in 1869 the first railroad was completed to the Pacific. The railroads opened up vast areas for settlement which had not been available before. This was particularly true of large areas west of the Mississippi, whose settlement and development, in the absence of navigable waterways, had to await the railroad. Fig. 279 shows the present railroad web.

By 1880, many parts of the West were settled (Fig. 280). Fertile soils had favored farming along the bases of some of the mountains and in many valleys, the discovery of mineral deposits had attracted thousands of prospectors and miners to various places, and the grazing industry supported a sparse population over wide areas.

The settlements in the Black Hills (Fig. 280) were the result of the recent discovery there of gold. Most of the settlers in central and western Montana were farmers, located chiefly in the valleys of the larger streams. Besides the farmers, there were some miners. In Colorado there were farmers (1) along the east base of the Rocky Mountains, where, at many points, irrigation was possible, and (2) in some of the mountain valleys. In addition, a large mining population had been attracted by the discovery, a few years before, of rich deposits of gold, silver, and lead in the Leadville district (p. 315). In New Mexico, the Rio Grande, Rio Pecos, and upper Canadian valleys had drawn many settlers. In Utah, the agricultural settlements of the Mormons extended along the base of the Wasatch Mountains, where there were fertile and irrigable soils (p. 291). The principal agricultural settlements in Nevada were in the Humboldt Valley and along the Central Pacific Railroad. The other settlements of the state depended chiefly on mining. In California, the commercial advantages of San Francisco Bay had attracted many people, and some of the gold-producing districts were well settled. The great central valley and the more inviting valleys of the Coast Range were occupied by farmers.

The lowlands west of the Cascade Mountains in Oregon and Washington were occupied for the most part, while in the drier regions east of those mountains most of the settlements were near the Columbia River and its tributaries. The remaining population of the West was scattered widely at military posts, mining camps, and on cattle ranches.

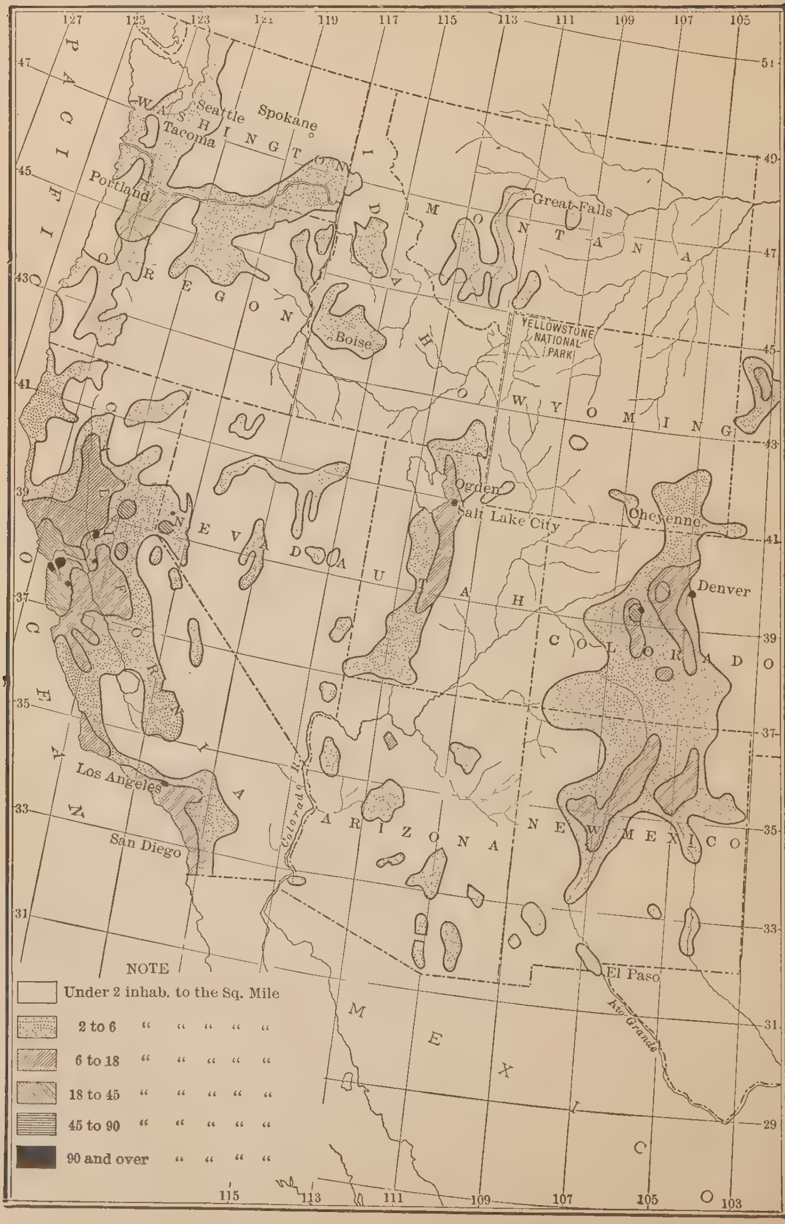


Fig. 280. Map showing distribution of population in the West in 1880.

The population map for 1900 (Fig. 281) will be understood readily in the light of the preceding discussion, and only its larger features need be noted here. The population of the eastern half of the country was seven times as great as that of the western half. The relatively sparse population of the western half was due chiefly to prevailing aridity and the great extent of mountains and plateaus. Furthermore, many of the settled areas were occupied only recently. The relation of precipitation to population is suggested by the fact that only about 1/30 of the people were in regions where precipitation is less than 20 inches. Similarly, the relation of altitude to population is shown by the fact that more than 95 per cent of the population lived at elevations of less than 2,000 feet. Since 1900, the population of many parts of the West has grown rapidly because of the development of irrigation, dry-farming, and mining, and the growth of commercial and industrial centers. The greatest densities (Fig. 281) are found in the northeastern quarter of the country. This region includes much of the glaciated area, with its highly productive soils; is unrivaled in its transportation facilities (Fig. 279); possesses vast resources in timber, in iron, coal, copper, and other useful minerals; and contains most of the great commercial and industrial centers of the country.

Cities

Cities have increased rapidly in the United States, both in number and size. In 1850, 12.5 per cent of the total population of the country lived in the 85 cities which had 8,000 or more people each; by 1900 the percentage of the population living in such cities had increased to 32.4, and the number of such cities to 517. Nearly half of the people of the country now live in villages and cities of more than 2,500 inhabitants. The increasing proportion of the population in cities has been due chiefly to the growth of urban commerce and industries (p. 383). The region with most cities is east of the Missouri River, and north of the Ohio and Potomac rivers. Here are 35 of the 50 cities which, in 1910, had a population greater than 100,000.

The leading types of cities are (1) commercial cities, (2) manufacturing cities, (3) mining cities, (4) political centers, and (5) health or pleasure resorts. Most large cities are both commercial and industrial centers, while some belong also in varying degree to one or more of the other classes.

Fig. 281. Map showing distribution of population in the United States in 1900.

Commercial cities. Cities dependent chiefly on commerce grow up (1) where conditions favor the collection and distribution of commodities on a large scale, or (2) on important lines of communication at points where the mode of transportation is changed. Such places are (1) seaports, (2) river ports, (3) lake ports, and (4) railroad centers.

(1) The growth of seaport cities is influenced mainly by (a) their position in relation to great trade routes; (b) the size, resources, population, and accessibility of their tributary areas (*hinterlands*); and (c) the character of their harbors. The ideal harbor is large enough to contain many vessels, deep enough to admit the largest ships, protected from storms, free from ice, connected with the open sea by a deep channel, and has shores of such a kind as to facilitate the building of docks and the handling of freight (p. 350). Commercial cities are likely to grow up at or near the mouths of navigable rivers, for the latter serve as highways into the interior, and in many cases afford good harbors. When the lower courses of rivers have deep channels, such cities may be some distance upstream, nearer the heart of the country. Thus Montreal, more than 800 miles inland, is, in effect, a seaport.

San Francisco has a fine harbor (Fig. 242), but trade with countries across the Pacific has been relatively unimportant; high mountains separate it from the interior; and to the east of these mountains stretch broad deserts with sparse populations. For years Boston, Philadelphia, and Baltimore, having good harbors and local hinterlands of importance, rivaled New York City in commercial importance. But the Hudson-Mohawk depression gave New York the best connections with the interior, and the opening of the Erie Canal (p. 286) added the Great Lakes Region to its hinterland, enabling it to leave the others behind.

(2) Since water transportation preceded railway transportation, most early inland cities are located at strategic points on navigable waterways. (a) At the head of river navigation goods are transferred from water to land, or vice versa, for further distribution, and hence commercial towns develop. Thus Haverhill grew up at the head of navigation on the Merrimac, Hartford on the Connecticut, Albany on the Hudson, Augusta on the Savannah, and St. Paul on the Mississippi. (b) River cities are found also at the junctions of large rivers, for such places are focal points for trade. Here traffic coming upstream is divided, a part going up each stream, while in many cases freight descending the tributary streams is transferred to boats operating on the main river. Pittsburgh

(p. 276), Cairo, St. Louis (p. 277), and Vicksburg are examples of places whose earlier growth, at least, was aided by their position near the junction of important streams. (c) A decided change in the direction of a river's course means a division of traffic and a change in the mode of carriage (Why?). Cincinnati (p. 276), Nashville, and Kansas City benefited from their positions on great bends of rivers. Kalamazoo, Michigan, and South Bend, Indiana, are types of many smaller places situated similarly. (d) Falls or rapids may give rise to a commercial city, for river freight must be unloaded, carried around the obstruction, and either reloaded or forwarded by land. The falls (rapids) of the Ohio made Louisville, those of St. Mary's River gave rise to Sault Ste. Marie, and the growth of Buffalo was aided by the falls and rapids of the Niagara.

(3) All the more important cities ranged along the Great Lakes started as commercial towns — as centers of exchange and transfer — and their commercial activities still dominate. As noted elsewhere (p. 279), their exact location was determined in most cases by natural lines of communication leading from the shores of the lakes.

Chicago became the greatest lake port because of its superior geographic advantages. (1) It is near the head of Lake Michigan, which extends farther than the other lakes into the heart of the country. (2) It is located more centrally than its rivals with reference to the richer areas of glacial soil and the areas leading in the production of corn (Fig. 259), wheat (Fig. 260), swine (Fig. 269), and cattle (Fig. 267). (3) All land traffic from the Northwest to the eastern part of the country must pass around Lake Michigan, and is therefore tributary to Chicago. The latter is accessible also by land from the south and east, from which directions many railroads have been built to Chicago to meet the traffic of the West and Northwest. Because of its strategic position, Chicago is the greatest railroad center in the world (Fig. 279).

The importance of water transportation to the growth of the leading cities of the country is shown by the fact that of the 28 cities having in 1910 a population of more than 200,000, 23 are on navigable waters. Of the 23, 10 are seaports, 7 are on the Mississippi System, and 5 are on the Great Lakes.

(4) All the important seaports, river ports, and lake ports of the United States are also more or less important as railroad centers. There are also a number of large cities without water transportation, like Indianapolis, which now owe their commercial importance largely or wholly to the fact that they are at the junction of several railroad lines. The greater cities of the United States had become important

because of their natural advantages, before the appearance of railroads. Railroads were built to them to share in existing trade, which they later helped to increase. On the other hand, the extension of railroads throughout the country caused a multitude of small cities and villages to spring up on sites without natural advantages. Such places serve as collecting and distributing points for the surrounding country, and, if railway junctions, they derive more or less benefit from the resulting exchange and transfer of traffic.

While the more important conditions which give rise to commercial centers have been mentioned, villages and cities may grow up at critical points on lines of communication for reasons not mentioned above. Thus a ford or ferry on a river may locate a town. Harrisburg, Pennsylvania, developed from Harris' Ferry, where a land route toward the west crossed the Susquehanna River; Zanesville, Lancaster, and Chillicothe, Ohio, grew up where an important early road (Zane's Trace) crossed the Muskingum, Hocking, and Scioto rivers. Again, a mountain pass upon which trade routes focus may give rise to a city. Cumberland, Maryland, has grown up in front of Wills Creek Water-Gap, important since the colonial period (p. 232). The growth of Denver has been stimulated by its relation to several of the passes in the Rocky Mountains.

Manufacturing cities. Most large commercial cities are important also as manufacturing centers (p. 383), for their transportation facilities make it easy to get raw materials together and to ship out the manufactured products. Labor, too, is abundant. New York, the commercial metropolis of the country, leads also in manufacturing; Chicago, the leading inland commercial city, is the second industrial center; and Philadelphia, the fourth commercial center, is third in industry. On the other hand, all industrial cities are necessarily, in varying degree, trade centers. In most cities, therefore, commercial and industrial activities are united in varying proportions determined largely by geographic conditions. The factors which control the distribution of manufacturing industries (pp. 379-383) control also the location of the cities to which those industries may give rise. Most distinctly industrial cities are located in response to (1) power resources, like many of the New England cities (p. 381), or (2) raw materials, like Birmingham, Alabama.

Mining cities. Many villages and cities, especially in the West, have developed from camps about mines. As the mining industry in a given locality grew, tents gave place to buildings of

wood and brick, business and professional men appeared to supply the needs of the miners, and busy settlements resulted, which in many cases became cities in a few years. Scranton (Pennsylvania), Joplin (Missouri), Deadwood (South Dakota), Cripple Creek (Colorado), Butte (Montana), and Placerville (California) are types of a large number of cities and towns which have grown up solely because of the wealth of adjacent mines.

Many cities at which there are no mines depend largely on the mining industry. Thus Pueblo (Colorado) and Anaconda (Montana) were founded chiefly for extracting metals from ores. Sacramento and Denver first became important as outfitting and supply stations for nearby mines. Indeed, there are few cities in the far West which have not been influenced by the mining industry.

Political centers. Few cities are merely political centers, for even though founded as such, their growth is almost certain to attract commercial, if not industrial, enterprises. Washington, D. C., is a striking exception. In locating state capitals, accessibility for the majority of the people has been a leading consideration. In states having a fairly uniform distribution of population and equal facilities for travel, the capital tends toward the geographic center. Thus the capital of Illinois shifted from Kaskaskia to Vandalia, and later to Springfield; that of Tennessee from Knoxville to Nashville; and that of Pennsylvania from Philadelphia to Harrisburg. The centrally located capitals of Ohio, Indiana, Iowa, Missouri, and South Dakota illustrate the same principle. On the other hand, where the mass of the population is in one section of the state, the capital is likely to be located there. Thus Boston, Albany, Lincoln, and Topeka, though far from the geographic centers of their respective states, are not far from the centers of population in each case. The question of accessibility was considered, among others, in choosing the site for the national capital, but with the growth of the West it has come to have a marginal location.

Health and pleasure resorts. The leading cities of this type have been stimulated in their growth by geographic conditions which make them attractive to the tourist or beneficial to the invalid; most of them are ocean, mountain, or mineral spring resorts. The attraction of the ocean resorts lies partly in their facilities for boating and bathing, but chiefly in the occurrence of the cool sea-breeze (p. 74) in the hot days of summer, and in the tempering effects of winds from the sea in winter. Newport and Atlantic City are exam-

ples. Asheville (North Carolina) and Colorado Springs are among the best-known mountain resorts (pp. 131, 317) of the United States, and Hot Springs, Arkansas, is the most prominent health resort created by "medicinal" springs (p. 211). Los Angeles and several neighboring places in southern California have become important resorts chiefly for climatic reasons.

Location of early cities. At one time people were gathered in villages and cities chiefly because of the necessity for defense. For this reason many old cities are located in places affording protection, as on hills and islands. Considerations of defense as well as of trade located many of the towns founded in this country during the colonial period.

The site of Boston was chosen because of (1) its strength for defense, (2) its harbor, and (3) a supply of good water. Boston peninsula was connected with the mainland by a narrow isthmus, so low that for years it was under water at high tide if a strong wind blew off the bay. This favored defense toward the land. The harbor is roomy, deep, farther inland than any other north of Cape Cod, and is located centrally on the coast of Massachusetts. This favored trade, and helped to make Boston the leading town of the colony. New York was founded on Manhattan Island for safety and in the expectation that the Hudson River would, as it did, give it command of the trade of a large district. Quebec was founded to guard the St. Lawrence highway and to command the fur trade of the Interior. The river is much narrower there than at any point farther downstream (Why advantageous?); the inland location was expected to afford security from European enemies; and the "Heights of Quebec" furnished an ideal site for a fortress. Montreal was laid out on a hilly island in the St. Lawrence River, opposite the mouth of the Ottawa River. Thus it was reasonably safe from unexpected attack, and able to draw upon the trade of both valleys.

Questions

1. Discuss the leading occupations of the United States as factors affecting density of population.

2. Why are there more important cities in the United States on the Atlantic coast than on the Pacific coast?

3. Compare and contrast the commercial advantages of the seaports of southeastern and northeastern United States.

4. Why are there fewer cities on the Great Lakes in Canada than in the United States?

5. Give examples, not mentioned in the text, of cities which have profited from their positions (1) on rivers at the head of navigation, (2) at the junctions of important rivers.

6. Lexington was for years the largest community in Kentucky. Now the population of Louisville is more than six times that of Lexington. Explain the change.

7. Why has Chicago derived greater commercial advantages from its location near the head of Lake Michigan, than Duluth has from its position near the head of Lake Superior?

8. Why are $^7/_{10}$ of the cities in the United States having in 1910 a population of more than 100,000 situated east of the Missouri River and north of the Ohio?

9. (1) Explain the relatively small population (1900) of (a) southern Florida and (b) northern Wisconsin and northern Michigan, as shown by Fig. 281

(2) Explain the distribution of population in (a) Montana, (b) the belt through southeastern Idaho and Utah, and (c) New Mexico.

(3) Account for the areas of relatively dense and of relatively sparse population in California.

(4) Cite illustrations (not involved in preceding questions) from the map, showing the influence on the distribution of population of (a) topography, (b) means of communication, and (c) natural resources.

10. (1) Why is the railroad web (Fig. 279) thickest in the northeastern quarter of the country?

(2) Account for the thinness of the railroad net in northern New England, northern New York, and the northern Lake Region.

(3) Why is the dominant direction of railroads east-west in the Great Plains?

(4) Why the relatively small railroad mileage of the western half of the country?

(5) Explain the distribution of railroads in California.

INDEX

REFERENCE BOOKS

The following list contains some sixty books on geography and related subjects which might well be in a high school library. If a reference library of twenty-five books were to be chosen from the list, those which are starred would be suggested as most suitable. If only ten books were to be chosen, those marked with two stars would be suggested.

BLACKWELDER AND BARROWS: *Elements of Geology*. New York: American Book Co., 1911. Price, $1.40.

Presents briefly the fundamental principles of geology; helpful in answering questions involving the relations of physiography and geology.

BRIGHAM: *Commercial Geography*. Boston: Ginn and Co., 1911. Price, $1.35.

Discusses at length wheat, cotton, cattle industries, iron, and coal, deducing from these the principles of commercial geography. Of commercial nations the United States is treated most fully. Many good maps and diagrams.

BRIGHAM: *Geographic Influences in American History*. Boston: Ginn and Co., 1903. Price, $1.25.

Traces in a suggestive way the effects of the larger geographic features of the United States on many leading events in its history.

** CHISHOLM: *Handbook of Commercial Geography*. New York: Longmans, Green and Co., 1912. (Revised edition.) Price, $4.80.

A great store of information about commodities of commerce and the commercial geography of all countries. Especially valuable for reference.

COMAN: *The Industrial History of the United States*. New York: The Macmillan Co., 1905. Price, $1.60.

Outlines the growth and expansion of the commerce and industries of the United States.

** DAVIS: *Physical Geography*. Boston: Ginn and Co., 1898. Price, $1.25.

Treats especially the life history of land forms. Excellent for discussion of coastal plains, stages of river development, and climatic control of land forms.

DAY: *A History of Commerce*. New York: Longmans, Green and Co., 1907. Price, $1.75.

Mainly historical, but traces many relations between earth features and the development of commerce since the earliest times.

DONDLINGER: *The Book of Wheat*. New York: Orange Judd Co., 1912. Price, $2.00.

An exhaustive discussion of the factors affecting the distribution of the world's wheat regions, together with all other aspects of wheat as a crop and a commodity of commerce.

DUTTON: *Earthquakes*. New York: G. P. Putnam's Sons, 1904. Price, $2.00.

Detailed, scientific treatise, covering the nature of earthquakes, their causes, the phenomena associated with them, and the leading features of the earthquake regions of the world.

GEIKIE, JAMES: *Earth Sculpture*. New York: G. P. Putnam's Sons, 1898. Price, $2.00.

Devoted entirely to the origin and development of land forms. Especially good for the effects of geological structure on topographic forms, and for glacial action.

* Geikie, Sir A.: *Elementary Lessons in Physical Geography.* New York: The Macmillan Co., 1900. Price, $1.10.

A simple and entertaining description of the more important aspects of physical geography.

Geikie, Sir A.: *Scenery of Scotland.* New York: The Macmillan Co., 1901. Price, $3.25.

Most interesting reading, full of information about processes of weathering and erosion, and particularly about features due to glaciation. Has a good chapter on the influence of physiography on the people of Scotland.

* Gifford: *Practical Forestry.* New York: D. Appleton and Co., 1902. Price, $1.20.

Simple, effective statements of the relations of forests to soils and stream flow, the factors affecting the distribution of forests, and the industrial importance of forests.

** Herbertson: *Man and his Work.* New York: The Macmillan Co., 1902. Price, 60 cents.

A very suggestive discussion of man's relations to his surroundings.

Herbertson: *Descriptive Geographies:* one volume each for *North America; Central and South America; Europe; Africa; Asia; Australia and Oceanica.* New York: The Macmillan Co., 1902–1903. Price, 70 to 90 cents per volume.

Collections of the best descriptions of typical sections of the different continents. Interesting and instructive supplementary reading.

Hogarth: *The Nearer East.* New York: D. Appleton and Co., 1902. Price, $2.00.

A regional study of Balkan Europe, Western Asia, and Egypt; considers fully the physiography and climate of these regions, and their relations to the life of the people.

* Holdich: *India.* New York: D. Appleton and Co., 1905. Price, $2.50.

Covers thoroughly every phase of the geography of British India. Especially good for the study of life conditions in a monsoon region.

* Hunt: *The Cereals in America.* New York: Orange Judd Co., 1908. Price, $1.75.

Excellent for details concerning soil and climatic requirements of cereal crops.

Johnson, E. R.: *Ocean and Inland Water Transportation.* New York: D. Appleton and Co., 1906. Price, $1.50.

Discusses fully the commercial importance of inland waterways and the chief problems in their use for navigation.

* Johnson, W. E.: *Mathematical Geography.* New York: American Book Co., 1907. Price, $1.00.

A standard reference for all matters concerning the form, motions, and dimensions of the earth, and for tides and map making.

Johnstone: *Conditions of Life in the Sea.* New York: G. P. Putnam's Sons, 1908. Price, $3.00.

Describes the plants and animals of the sea, their distribution, and their uses by man. Good also for methods of exploration of the sea and the main features of the North Atlantic Ocean.

* Keltie (Editor): *The Statesman's Yearbook.* New York: The Macmillan Co., 1863–1911. Price, $3.00.

An annual publication giving current statistics for all countries. Gives also brief statements about government, education, currency, defence, etc., for most countries.

* King: *Farmers of Forty Centuries.* Madison, Wis.: Mrs. F. H. King, 1911. Price, $2.50.

Describes agricultural systems of China and Japan, and tells much about the effects of geography on the life of the people.

** KING: *The Soil.* New York: The Macmillan Co., 1907. Price, $1.50.
An exhaustive, but simple, description of soil types, their formation, and characteristics. Especially good for discussion of soil moisture.

** KING: *Irrigation and Drainage.* New York: The Macmillan Co., 1909. Price, $1.50.
Treats in detail the relation of water to plant growth, the soil and climatic conditions which make irrigation necessary, the effectiveness of conserving water by tillage, and the general problems of irrigation farming. Wet lands and their drainage are considered more briefly.

KIRCHOFF: *Man and Earth* New York: E. P. Dutton and Co., (n.d.p.). Price, 75 cents.
A small book with many good examples of man's relations to his surroundings, especially in Great Britain, the United States, Germany, and China.

LITTLE: *The Far East.* New York: D. Appleton and Co., 1905. Price, $2.00.
A regional study of China and Japan along the same lines as Hogarth's "The Nearer East" (q.v.).

LYDE: *Man and his Markets.* New York: The Macmillan Co., 1901. Price, 50 cents.
Good material on many of the larger aspects of commercial geography, presented in a new way.

* MACKINDER: *Britain and the British Seas.* New York: D. Appleton and Co., 1902. Price, $2.00.
A comprehensive study of every phase of the geography of the British Isles. Especially valuable for the ten chapters tracing the effects of physical conditions on the development of the four countries.

MEAD: *Story of Gold.* New York: D. Appleton and Co., 1906. Price, 75 cents.
Describes the conditions of occurrence of gold, the methods of mining, the chief gold regions of the world, and the importance of gold in industry and coinage.

MILHAM: *Meteorology.* New York: The Macmillan Co., 1912. Price, $4.50.
Embodies the latest results of the investigation of atmospheric phenomena. Especially good on atmospheric moisture and irregular winds.

** MILL (Editor): *The International Geography.* New York: D. Appleton and Co., 1905. Price, $3.50.
A handbook giving the main geographical aspects of all countries, by seventy authors.

MILL: *The Realm of Nature.* New York: Chas. Scribner's Sons, 1892. Price, $1.50.
An elementary and stimulating treatment of physiography from the English viewpoint. Traces the interdependence of the different aspects of nature.

* MOORE, W. L.: *Descriptive Meteorology.* New York: D. Appleton and Co., 1910. Price, $3.00.
A general text, less advanced than Milham (q.v.); especially good for methods of weather forecasting. An appendix of 45 valuable charts.

* MOULTON: *An Introduction to Astronomy.* New York: The Macmillan Co., 1906. Price, $1.60.
A clear, comprehensive exposition of modern astronomy. Especially good for discussion of the evolution of the solar system, and the planetary relations of the earth.

NEWELL: *Irrigation.* New York: T. Y. Crowell and Co., 1906. Price, $2.00.
Describes in detail the conditions of arid United States, the supplies of water, the methods of storing and distributing water, irrigation law, the irrigated regions of the West, and the relation of irrigation to crops in the other parts of the country.

PARTSCH: *Central Europe.* New York: D. Appleton and Co., 1903. Price, $2.00.
Deals mainly with Germany and Austria-Hungary in a manner similar to Hogarth's "The Nearer East" (q.v.).

RUSSELL: *North America.* New York: D. Appleton and Co., 1904. Price, $2.00.
Treats in detail the coasts, topography, geology, and climate of the United States, and considers less fully the other parts of the continent. Discusses also distribution of plant and animal life.

RUSSELL: *Glaciers of North America.* Boston: Ginn and Co., 1897. Price, $1.75.
Same type of book as Russell's "Rivers of North America" (q.v.).

* RUSSELL: *Rivers of North America.* New York: G. P. Putnam's Sons, 1898. Price, $2.00.
An extensive treatment of the characteristics and work of streams. Good descriptions of the main river systems of the continent.

RUSSELL: *Volcanoes of North America.* New York: The Macmillan Co., 1897. Price, $4.00.
Same type of book as Russell's "Rivers of North America" (q.v.).

RIES: *Economic Geology.* New York: The Macmillan Co., 1910. Price, $3.50.
Explains the formation and distribution of mineral deposits. Much information about important regions of mineral production.

** SALISBURY: *Physiography: Briefer Course.* New York: Henry Holt and Co., 1908. Price, $1.50.
A general text which emphasizes physiographic processes and their effects on land forms.

** SEMPLE: *Influences of Geographic Environment.* New York: Henry Holt and Co., 1911. Price, $4.00.
Deals mainly with human responses to geographic conditions in typical environments. Large amount of excellent material for supplementary reading.

* SEMPLE: *American History in its Geographic Conditions.* Boston: Houghton, Mifflin and Co., 1903. Price, $3.00.
Traces the influence of geography on United States history. Enriches the study of either subject.

SHALER: *Aspects of the Earth.* New York: Chas. Scribner's Sons, 1889. Price, $2.50.
A popular account of some of the larger features of earth science. Very suggestive on "Caverns and Cavern Life" and on "The Origin and Nature of Soils."

* SHALER: *Man and the Earth.* New York: Fox, Duffield and Co., 1905. Price, $1.50.
States in an interesting and convincing way man's dependence on the resources of the earth, and the need for conserving them.

SHALER: *Nature and Man in America.* New York: Chas. Scribner's Sons, 1893. Price, $1.50.
Discusses the influences of environment on man's progress in civilization, and especially the effects of the physical features of North America on the settlement and development of the continent.

SHALER: *The Story of Our Continent.* Boston: Ginn and Co., 1897. Price, 75 cents.
A short, simple account of the geologic development of North America, the present condition of the continent, and of some of the larger effects of geography on the people.

SHALER: *Sea and Land.* New York: Chas. Scribner's Sons, 1894. Price, $2.50.
Features of coasts and oceans, with their influences on man. Excellent for material on harbors.

SMITH: *The Story of Iron and Steel.* New York: D. Appleton and Co., 1908. Price, 75 cents.
A non-technical description of the industry and its development, particularly in the United States.

REFERENCE BOOKS

* STANFORD (Publisher): *Compendium of Geography and Travel.* Twelve volumes. London: Edward Stanford, 1895–1908. Price, $5.50 per volume.

Volumes for each of the continents, describing their physiography, climate, resources, and something of the development of each of their countries.

SURFACE: *The Story of Sugar.* New York: D. Appleton and Co., 1910. Price, $1.00.

Discusses the natural conditions required for sugar cane and sugar beets, the sugar regions of the world, the processes of manufacturing sugar, and its commercial importance.

TAYLOR: *Australia: Physiographic and Economic.* Oxford, Eng.: Clarendon Press, 1911. Price, 90 cents.

An excellent analysis of the natural regions of Australia and their relations to the economic development of the country. Many good maps and diagrams.

TOWER: *The Story of Oil.* New York: D. Appleton and Co., 1909. Price, $1.00.

An account of the development of the petroleum industry, mainly in the United States. Discusses also commercial and industrial importance of petroleum products.

** VAN HISE: *Conservation of Natural Resources in the United States.* New York: The Macmillan Co., 1910. Price, $2.00.

Considers our resources in minerals, forests, waters, and lands; the ways in which their use now involves needless waste; and the remedies which should be adopted to check these wastes. Outlines the recent Conservation Movement.

** WARD: *Climate.* New York: G. P. Putnam's Sons, 1908. Price, $2.00.

A full description of all the important types of climate, and of their influence on various human activities.

WARREN: *Elements of Agriculture.* New York: The Macmillan Co., 1910. Price, $1.10.

Discusses the conditions of plant growth, the mineral plant foods, the raising of the chief farm crops and of live stock, and the problems of farm management.

* WIDTSOE: *Dry Farming.* New York: The Macmillan Co., 1911. Price, $1.50.

Explains the principles of conserving soil moisture, the water requirements of different crops, the conditions in regions of scanty rainfall, and states what can be done to reclaim these regions for agriculture.

WILLIS: *Agriculture in the Tropics.* Cambridge, Eng.: Cambridge University Press, 1909. Price, $2.50.

States concisely the relations of soil, climate, and labor to farming in tropical lands, with accounts of the chief tropical crops. Examples drawn mainly from Ceylon and India.

GOVERNMENT PUBLICATIONS

Much supplementary material may be found in government publications, some of which are noted below, with the addresses from which they may be obtained. Lists of government publications on different topics, as geography, may be obtained by addressing: The Superintendent of Public Documents, Washington, D. C.

BUREAU OF THE CENSUS: *Reports* and *Bulletins of the Census.* These furnish statistical and other data concerning population, industries, etc., in the United States. Address: The Director, Bureau of the Census, Washington, D. C.

REFERENCE BOOKS

DEPARTMENT OF AGRICULTURE: (1) *Yearbook of the Department of Agriculture.* An annual publication containing detailed statistics of agriculture for the United States and general statistics for foreign countries. Also has special articles bearing on farm industries. Obtainable through local representatives in Congress. (2) *List of Publications.* A monthly circular giving titles of current publications of the Department, including *Bulletins* and *Circulars* of the FORESTRY SERVICE, and publications of the WEATHER BUREAU. Address: The Editor and Chief, Division of Publications, Dept. of Agriculture, Washington, D. C.

U. S. GEOLOGICAL SURVEY: (1) *Topographic maps* of many parts of the country; (2) *Mineral Resources of the United States*, an annual publication; (3) *Annual Reports;* (4) *Professional Papers;* (5) *Bulletins;* and (6) *Water Supply and Irrigation Papers.* Many of the above contain much supplementary material for work in geography. The *Press Bulletins* of the Survey are leaflets issued at frequent intervals, which contain current items of interest, especially in regard to economic aspects of the work of the Bureau. Address: The Director, U. S. Geological Survey, Washington, D. C.

DEPARTMENT OF COMMERCE AND LABOR: (1) *Monthly Summary of Commerce and Finance;* (2) *Commerce and Navigation of the United States;* and (3) *Commercial Relations of the United States.* These contain elaborate statistical data concerning the foreign commerce of the country. The last named, an annual volume, discusses our trade with each foreign country. The volume on *Commerce and Navigation* (annual) gives statistics by countries, commodities, and ports of entry or shipment. Address: The Secretary, Department of Commerce and Labor, Washington, D. C.

MAGAZINES

The geographical magazines noted below are important helps to students and teachers of geography:

Bulletin of the American Geographical Society. New York: Broadway and 156th Street. $5 per year.

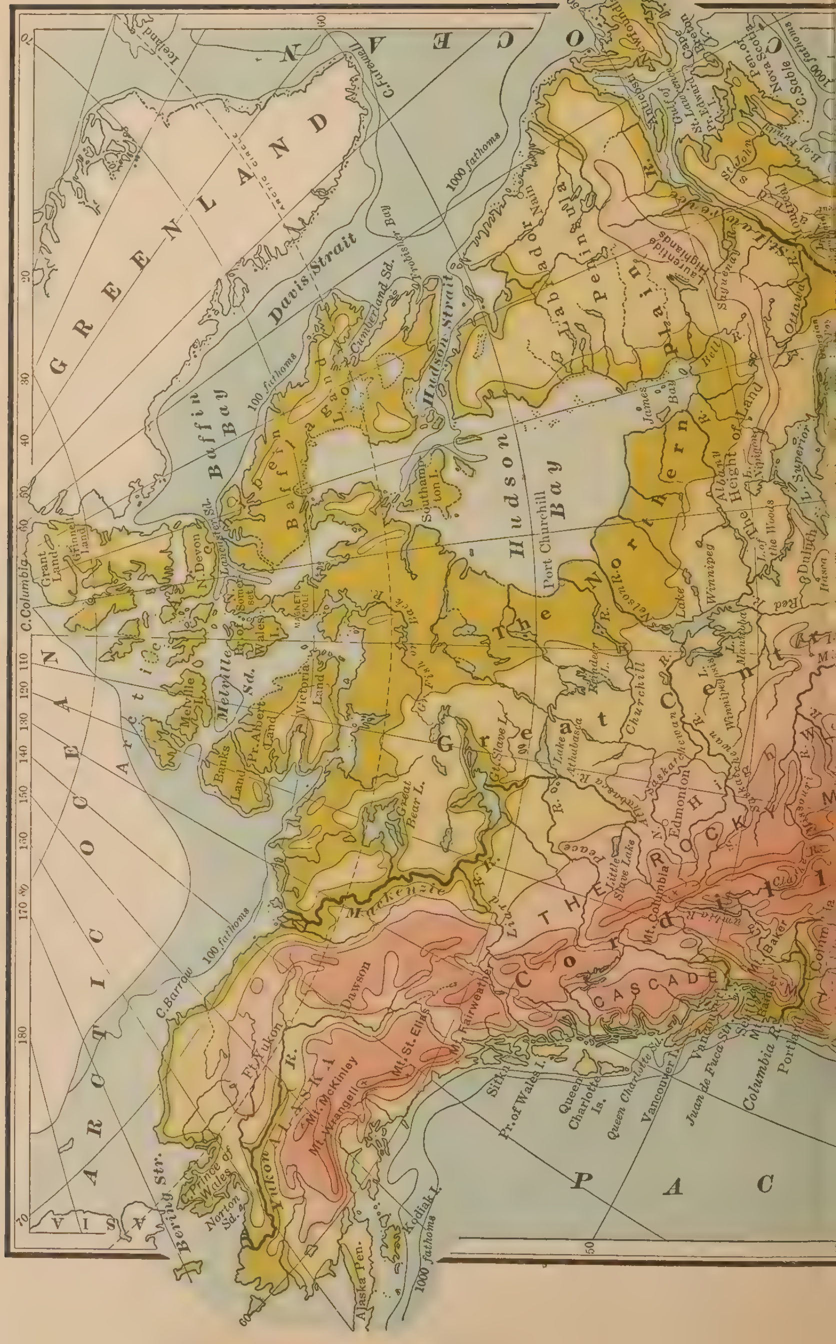
Geographical Journal. London: Royal Geographical Society. 27 s. per year.

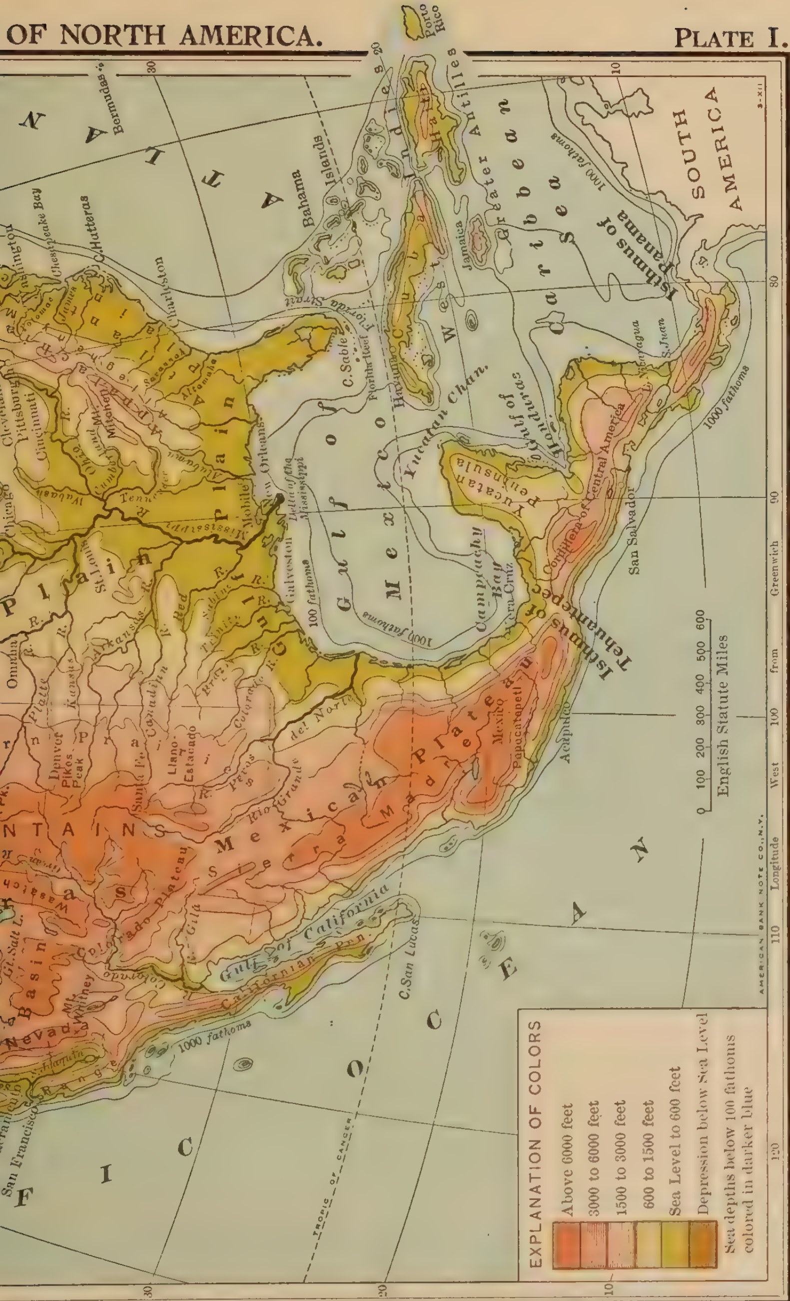
Journal of Geography. Madison, Wis.: University of Wisconsin. $1.00 per year.

National Geographic Magazine. Washington, D. C.: 16th and M Streets, N. W. $2.50 per year.

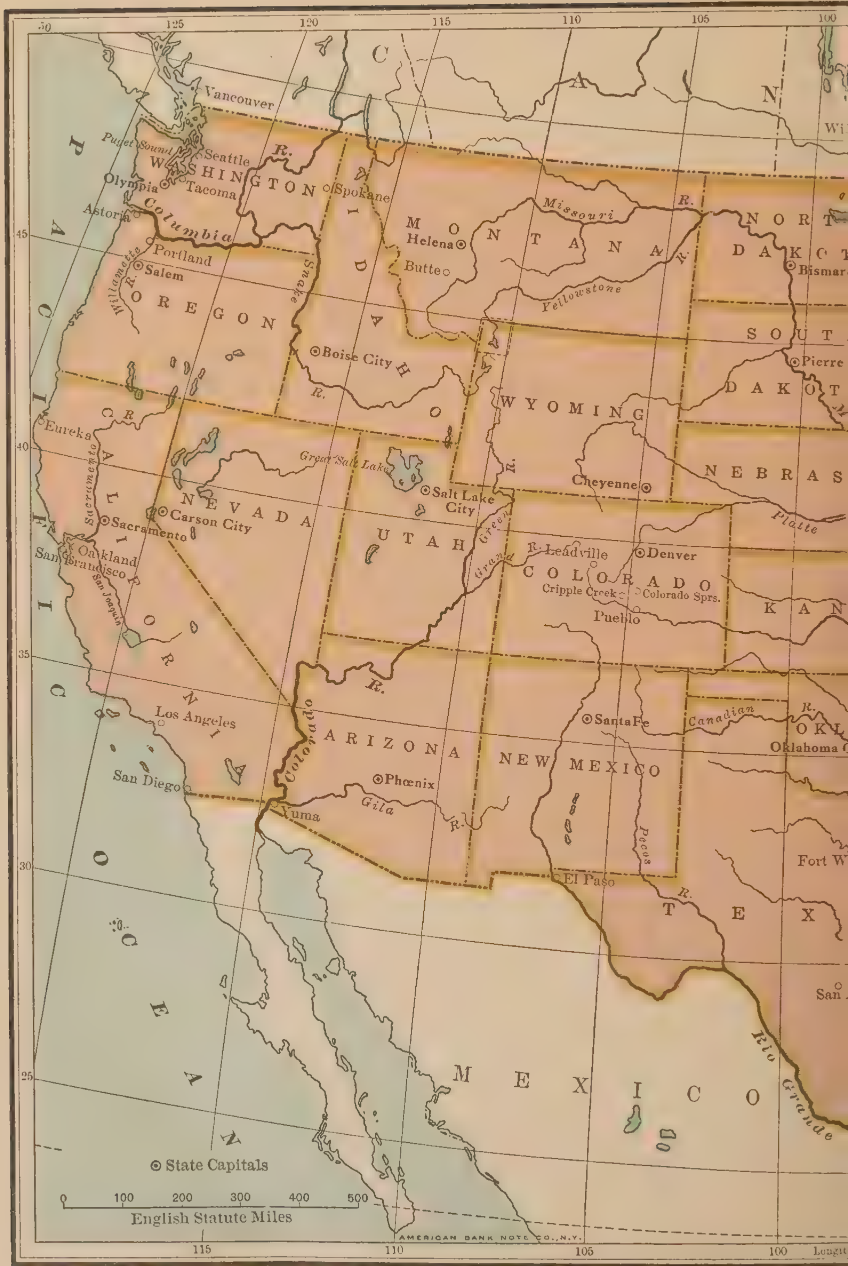
Scottish Geographic Magazine. Edinburgh: Royal Scottish Geographical Society. 18 s. per year.

PHYSICAL


GREENLAND
OCEAN
Iceland
Davis Strait
Baffin Bay
Cumberland Sd.
Frobisher Bay
C. Farewell
1000 fathoms
100 fathoms
Hudson Strait
Hudson Bay
James Bay
Southampton I.
Port Churchill
Labrador
Nain
Peninsula
Laurentide Highlands
St. Lawrence R.
Gulf of St. Lawrence
Anticosti
Newfoundland
C. Race
Cape Breton I.
Pr. Edward I.
Nova Scotia
C. Sable
B. of Fundy
St. John
Montreal
Ottawa
Saguenay R.
Bell R.
Albany R.
Height of Land
L. Nipigon
L. Superior
Duluth
L. of the Woods
Red R.
Lake Winnipeg
Winnipegosis L.
Manitoba L.
Nelson R.
Churchill R.
Reindeer L.
Saskatchewan R.
Edmonton
Lake Athabasca
Athabasca R.
Gt. Slave L.
Great Bear L.
Back R.
Peace R.
Little Slave Lake
Mackenzie R.
Liard R.
The Great Northern Plain
THE ROCKY MTS.
Cordillera
CASCADE
Mt. Columbia
Columbia R.
Mt. Baker
Mt. Rainier
Portland
Vancouver I.
Juan de Fuca Str.
Queen Charlotte Sd.
Queen Charlotte Is.
Sitka
Pr. of Wales I.
Mt. Fairweather
Mt. St. Elias
Dawson
Ft. Yukon
Yukon R.
ALASKA
Mt. McKinley
Mt. Wrangell
Kodiak I.
Alaska Pen.
Norton Sd.
C. Prince of Wales
Bering Str.
ASIA
C. Barrow
ARCTIC OCEAN
Arctic
Banks Land
Pr. Albert Land
Victoria Land
Melville I.
Melville Sd.
N. Somerset
Pr. of Wales I.
MAGNETIC POLE
Baffin Land
Lancaster Sd.
N. Devon
Grant Land
Grinnell Land
C. Columbia
Arctic Circle
PACIFIC


Bermudas
Bahama Islands
Porto Rico
West Indies
Greater Antilles
Haiti
Cuba
Havana
Jamaica
Caribbean Sea
Isthmus of Panama
SOUTH AMERICA
1000 fathoms
C. Hatteras
Chesapeake Bay
Charleston
Atlantic Plain
Appalachian Mts.
Pittsburgh
Cincinnati
Cleveland
Chicago
St. Louis
Mississippi R.
Ohio R.
Tennessee R.
Alabama R.
Altamaha
Savannah
Mobile
New Orleans
Galveston
Delta of the Mississippi
Florida Strait
C. Sable
Florida Reef
Gulf of Mexico
100 fathoms
1000 fathoms
Yucatan Chan.
Gulf of Honduras
Yucatan Peninsula
Campeachy Bay
Vera Cruz
Central America
Cordillera of Central America
L. Nicaragua
S. Juan
San Salvador
Isthmus of Tehuantepec
Mexican Plateau
Sierra Madre
Mexico
Popocatepetl
Acapulco
Rio Grande del Norte
Pecos R.
Llano Estacado
Colorado R.
Brazos R.
Trinity R.
Sabine R.
Red R.
Arkansas R.
Canadian R.
Platte R.
Kansas R.
Omaha
Denver
Pikes Peak
Santa Fe
Prairie
Colorado Plateau
Gila R.
Wasatch
Gt. Salt L.
Great Basin
Mt. Whitney
Sierra Nevada
San Francisco
Gulf of California
Californian Pen.
C. San Lucas
Tropic of Cancer
Pacific Ocean
0 100 200 300 400 500 600
English Statute Miles
Longitude West from Greenwich
EXPLANATION OF COLORS
Above 6000 feet
3000 to 6000 feet
1500 to 3000 feet
600 to 1500 feet
Sea Level to 600 feet
Depression below Sea Level
Sea depths below 100 fathoms colored in darker blue
AMERICAN BANK NOTE CO., N.Y.

MAP OF TH



Vancouver
Puget Sound
Seattle
WASHINGTON
Olympia
Tacoma
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Astoria
Columbia
Portland
Salem
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OREGON
Snake
IDAHO
Boise City
MONTANA
Helena
Butte
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Yellowstone
NORTH DAKOTA
Bismarck
SOUTH DAKOTA
Pierre
WYOMING
Cheyenne
NEBRASKA
Platte
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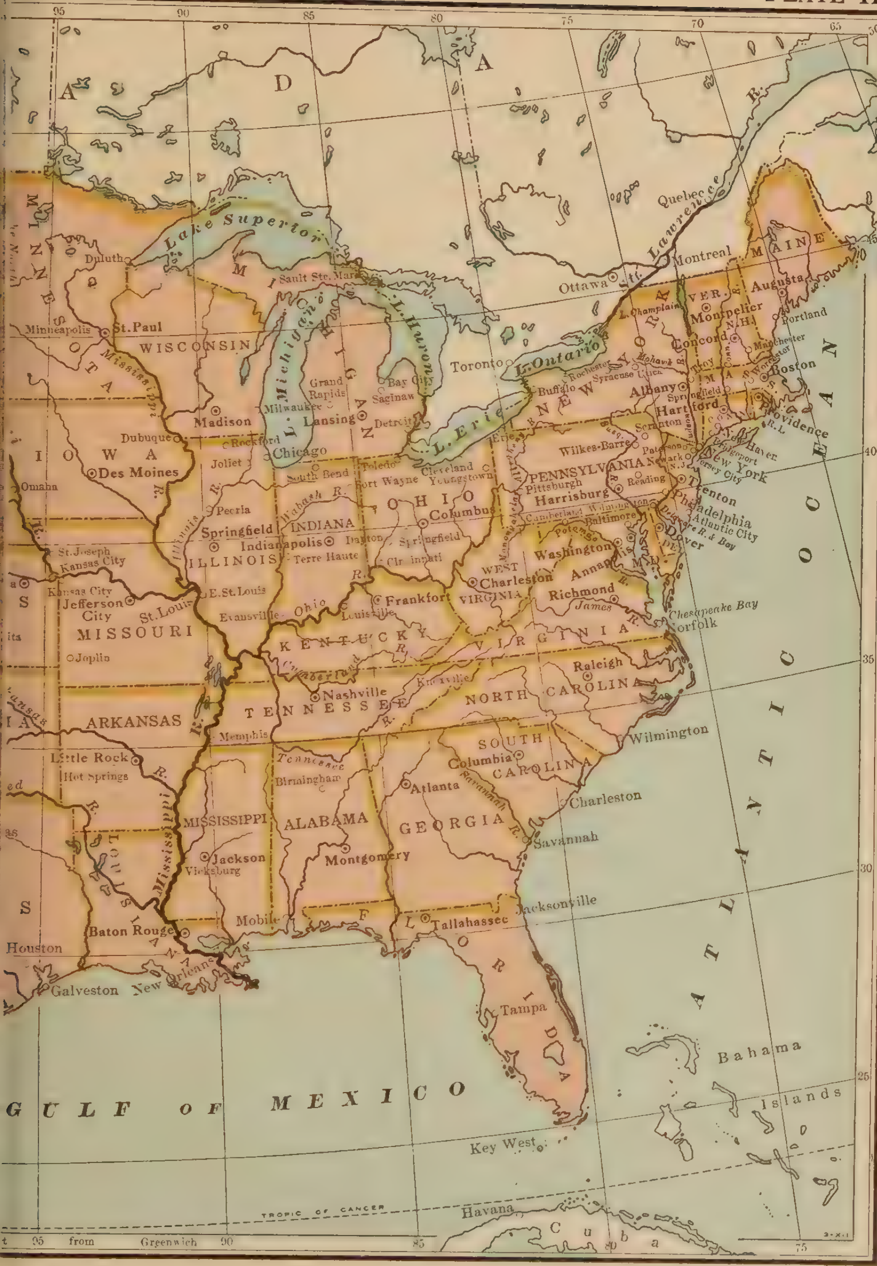
Sacramento
CALIFORNIA
NEVADA
Carson City
Great Salt Lake
Salt Lake City
UTAH
Green
Grand
Leadville
Denver
COLORADO
Cripple Creek
Colorado Sprs.
Pueblo
KANSAS
Oakland
San Francisco
San Joaquin
Los Angeles
San Diego
Colorado
ARIZONA
Phœnix
Gila
Yuma
NEW MEXICO
Santa Fe
Canadian
Pecos
El Paso
OKLAHOMA
Oklahoma C
TEXAS
Fort W
San
Rio Grande
MEXICO
PACIFIC OCEAN
State Capitals
English Statute Miles
AMERICAN BANK NOTE CO., N.Y.



Lake Superior
L. Michigan
L. Huron
L. Erie
L. Ontario
L. Champlain
St. Lawrence
Quebec
Montreal
Ottawa
Toronto
MAINE
Augusta
Portland
VER.
Montpelier
N.H.
Concord
Manchester
Worcester
Boston
MASS.
Springfield
Providence
R.I.
CONN.
Hartford
New Haven
Bridgeport
NEW YORK
Albany
Troy
Utica
Syracuse
Rochester
Buffalo
Mohawk
New York
Jersey City
Newark
Paterson
N.J.
Trenton
Philadelphia
Atlantic City
Delaware R. & Bay
DEL.
Dover
PENNSYLVANIA
Erie
Scranton
Wilkes-Barre
Reading
Harrisburg
Pittsburgh
Allegheny
Wilmington
Baltimore
Cumberland
MD.
Annapolis
Washington
Potomac
Richmond
James R.
VIRGINIA
Chesapeake Bay
Norfolk
WEST VIRGINIA
Charleston
OHIO
Columbus
Cleveland
Youngstown
Toledo
Dayton
Springfield
Cincinnati
Ohio R.
MICHIGAN
Detroit
Lansing
Grand Rapids
Saginaw
Bay City
Sault Ste. Marie
INDIANA
Indianapolis
Fort Wayne
South Bend
Terre Haute
Evansville
Wabash R.
ILLINOIS
Springfield
Chicago
Rockford
Joliet
Peoria
E. St. Louis
WISCONSIN
Madison
Milwaukee
MINNESOTA
St. Paul
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Duluth
Mississippi R.
IOWA
Des Moines
Dubuque
Omaha
MISSOURI
Jefferson City
St. Louis
Kansas City
St. Joseph
Joplin
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Frankfort
Louisville
Cumberland R.
TENNESSEE
Nashville
Knoxville
Memphis
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NORTH CAROLINA
Raleigh
Wilmington
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Columbia
Charleston
GEORGIA
Atlanta
Savannah
Savannah R.
ALABAMA
Montgomery
Birmingham
Mobile
MISSISSIPPI
Jackson
Vicksburg
ARKANSAS
Little Rock
Hot Springs
LOUISIANA
Baton Rouge
New Orleans
Houston
Galveston
FLORIDA
Tallahassee
Jacksonville
Tampa
Key West
GULF OF MEXICO
ATLANTIC OCEAN
Bahama Islands
Cuba
Havana
TROPIC OF CANCER
95 from Greenwich 90

PHYSICAL MAP

PHYSICAL

BASED ON BARTHOLOMEW'S COMPARATIVE ATLAS. LONDON: MEIKLEJOHN AND HOLDEN

Nova Zembla
Tundras
URAL MOUNTAINS
R. Ob or Obi
ASIA
White Sea
Archangel
R. Mezen
R. Pechora
R. Dwina
R. Vichegda
R. Onega
L. Onega
L. Ladoga
St. Petersburg
Neva
R. Sukhona
Perm
Kama
Volga
Nijni Novgorod
Valdai Hills
Moscow
R. Oka
R. Duna
Plain
R. Dnieper
R. Dniester
R. Don
Odessa
Sea of Azov
Crimea
R. Kuban
Steppes
Caspian Depression Below Ocean Level
R. Ural
Astrakhan
Aral Sea
Caspian Sea
100 fathoms
CAUCASUS MTS.
Mt. Elbruz
Black Sea
100 fathoms
1000 fathoms
Bosporus
Danube
Iron Gates
Balkan Mts.
Sophia
Constantinople
Sea of Marmora
Dardanelles
ASIA MINOR
Aegean Sea
Candia
Cyprus
EXPLANATION OF COLORS
Above 6000 feet
3000 to 6000 feet
1500 to 3000 feet
600 to 1500 feet
Sea Level to 600 feet
Depression below Sea Level
Sea depths below 100 fathoms colored in darker blue

PHYSICAL M


A R C T I C
ARCTIC CIRCLE
100 fathoms
Nova Zembla
Kara Sea
North Sea
White Sea
Baltic Sea
R. Dwina
Great Lowland Plain
E U R O P E
R. Rhine
R. Elbe
R. Dnieper
R. Volga
R. Danube
Constantinople
Dardanelles
R. Don
Astrakhan
Caspian Depression below Ocean Level
Black Sea
Bosporus
Mt. Elburz
Caucasus Mts.
Batum
Tableland of Asia Minor
Taurus Mts.
Armenian and Kurdistan Highlands
Mediterranean Sea
Cyprus
Alexandria
Cairo
Lebanon Mts.
Syrian Desert
Dead Sea
Isthmus of Suez
R. Euphrates
R. Tigris
Mesopotamian Plains
Caspian Sea
85 ft. below Ocean Level
Elburz Mts.
Salt Desert
Kirghiz Steppes
Aral Sea
Sur Daria
Amu Daria
Khiva
Atrek R.
Plateau of Iran
Koh-rud Mts.
Nefud Desert
Nejd Tableland of Arabia
Mecca
Persian G.
Str. of Ormuz
G. of Oman
A F R I C A
R. Nile
Red Sea
Str. of Bab-el-Mandeb
Gulf of Aden
Socotra I.
100 fathoms
Arabian Sea
I N D I A N O
Hindu Kush
Khaiber Pass
Bolan Pass
Suliman Mts.
R. Indus
Delta of the Indus
Pamirs
Karakoram Mts.
Tien
Tobolsk
R. Tobol
R. Ishim
R. Obi
G. of Obi
L. Balkash
R. Sutlej
Delhi
Plains
Vindhya Mts.
R. Narbada
Tapti
G. of Cambay
Bombay
Plateau of the Deccan
R. Godavari
Western Ghats
Eastern Ghats
C. Comorin
100 fathoms
EXPLANATION OF COLORS
Above 6000 feet
3000 to 6000 feet
1500 to 3000 feet
600 to 1500 feet
Sea Level to 600 feet
Depression below Sea Level
Sea depths below 100 fathoms colored in darker blue
0 200 400 600
English Statute Miles
AMERICAN BANK NOTE CO., N.Y.
Longitude East from
60 10 70 0 10 20 30 40 50 60 70
50 40 30 20 10 0
40 50 60 70 80

ASIA.

PLATE V.

Bering Strait
Gulf of Anadyr
Delta of the Lena
Siberian Plain
Bering Sea
Verkhoyansk
Stanovoi Mts.
Kamchatka Pen.
Okhotsk
100 fathoms
Sea of Okhotsk
Yakutsk
Lower Tunguska
Sakhalin Island
Kurile Islands
Nikolaievsk
Yablonoi Mts.
Lake Baikal
Irkutsk
Khinghan Mts.
R. Kerulen
Yezo
Vladivostok
Sea of Japan
Hondo
Tokio
Yokohama
Fujiyama
Altai Mts.
Mongolian Plateau
Shamo
Gobi
Pt. Arthur
Peking
G. of Pechili
Great Plain of China
Yellow Sea
Korea
Korea Strait
Shikoku
Kiushiu
Nan Shan
Shanghai
East China Sea
Tsinling Mts.
Hankow
Yunling Mts.
Plateau of Tibet
Lhasa
Kanchanjanga
Foochow
Formosa Str.
Formosa
Tropic of Cancer
Nanling Mts.
Canton
Hongkong
Hainan
Gulf of Tonking
Hanoi
Hue
Luzon I.
PHILIPPINE ISLANDS
Manila
Samar
Mindoro
Delta of the Ganges
Indo China Peninsula
Rangoon
Bangkok
Delta of the Irawadi
Bay of Bengal
Gulf of Siam
Palawan
Sulu Sea
Mindanao I.
South China Sea
C. Cambodia
Sulu Archipelago
Celebes Sea
Equator
Strait of Malacca
Malay Pen.
Singapore
Sumatra
BORNEO
Celebes
Molucca Is.
New Guinea
PACIFIC OCEAN
JAPAN


EUROPE
ASIA
ARABIA
SUDAN
Bay of Biscay
C. Finisterre
SPAIN
Corsica
Sardinia
Balearic Is.
ITALY
Adriatic Sea
R. Danube
TURKEY
Black Sea
100 fath.
Caspian Sea
Aral Sea
MEDITERRANEAN SEA
1000 fath.
1000 fathoms
Sicily
GREECE
Crete
Cyprus
C. St. Vincent
Strait of Gibraltar
Ceuta
Algiers
Tunis
Madeira Is.
Canary Is.
C. Bojador
C. Blanco
Morocco
Atlas Mts.
Algerian Plateau
Wady Draa
G. of Gabes
Tripoli
Gulf of Sidra
Barka Plateau
Delta of the Nile
Suez Canal
Alexandria
Isthmus of Suez
Suez
Cairo
G. of Akaba
Persian Gulf
Wargla
Algerian Sahara
Oasis of Ghadames
El Erg
Oasis of Gurara
Oasis of Tuat
Tasili Plateau
Oases of Ghat
Oasis of Fezzan
Oasis of Aujila
Oases of Siwa
Oases of Kufra
Oasis
Libyan Desert
Sahara or Great Desert
R. Nile
Arabian Desert
Berenice
RED SEA
Assuan
1st Cataract
2nd Cat.
3rd Cat.
4th Cat.
5th Cat.
TROPIC OF CANCER
Ahaggar Pl.
El Juf
Tibesti
Tarso Mts.
Borku
Nubian Desert
Suakin
Berber
Dongola
Oasis of Kawar
Air or Asben
Adghagh Plateau
Timbuktu
Hombori Mts.
R. Senegal
St. Louis
C. Verde
R. Gambia
Joliba
Bani R.
Sokoto R.
Kano
Chaba
L. Chad
Bahr el Ghazal
El Fasher
El Obeid
Khartum
R. Atbara
El Gash
Blue Nile
Bahr el Azrek
Bahr el Abiad
Plateau of Abyssinia
Tana
Strait of Bab-el-Mandeb
Gulf of Aden
Socotra
Cape Guardaful
Berbera
Nogal Pl.
W. Nogal
Salamat
Bahr el Arab
Yakoba
R. Benue
Logone
R. Shari
Mt. Alantika
Mt. Loma
Mt. Daro
Freetown
Sobat R.
30
20
10
0
10
20
30
40
50
60
40
30
20
10

D ON BARTHOLOMEW'S COMPARATIVE ATLAS. LONDON: MEIKLEJOHN AND HOLDEN

PHYSICAL M

BASED ON BARTHOLOMEW'S COMPARATIVE ATLAS. LONDON: MEIKLEJOHN AND HOLDEN


Neu Pommern
Bougainville
Solomon
Islands
1000 fathoms
C. Flattery
Barrier Reef
Halifax B.
Port Denison
Fitzroy R.
Rockhampton
C. Sandy
Darling Downs
Brisbane
Warrego
Culgoa R.
Barwan R.
New England Ra.
Liverpool Ra.
Blue Mts.
Port Jackson
Sydney
Australian Alps
Mt. Townsend
C. Howe
Wilson Promontory
South Cape
New Hebrides
New Caledonia
Loyalty Is.
PACIFIC
OCEAN
1000 fathoms
North Cape
Auckland
North Island
Bay of Plenty
East Cape
Hawke B.
NEW ZEALAND
C. Farewell
Nelson
Wellington
Cook Str.
South Island
Southern Alps
1000 fathoms
West Cape
Dunedin
South C.
150
160
170
180
10
20
30
40